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# Multimedia Environmental Assessment of Electric Submerged Arc Furnaces Producing Ferroalloys

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# MULTIMEDIA ENVIRONMENTAL ASSESSMENT OF ELECTRIC SUBMERGED ARC FURNACES PRODUCING FERROALLOYS

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16. ABSTRACT The report gives results of sampling and analysis at five ferroalloy plants to determine the amounts of particulates and organics generated during manufacture of several products, the effect of furnace type on the amounts generated, and the amounts of these materials escaping to the environment. Simultaneous samples, by modified EPA Method 5, were taken before and after the baghouse emission control systems of three open furnaces producing silicon metal (Si), high-carbon ferromanganese (H.C. FeMn), and 50 percent grade ferrosilicon (FeSi). Simultaneous samples, by modified EPA Method 5, were taken after the primary emission control scrubbers and of fume in the secondary emission control systems and of the scrubber discharge water, by automatic compositing samples, of two semi-enclosed furnaces producing H.C. FeMn and 50 percent grade FeSi. Samples were also taken of the influent to and effluent from two plant wastewater treatment systems and groundwater samples around the waste disposal area of one plant. Particulate emissions ranged from 0.078 kg/MW-hr for the open FeMn furnace to 1.22 kg/MW-hr for the Si furnace. More organics are emitted to the atmosphere than particulates. Open furnaces emit as much as or more organics to the atmosphere than do semi-enclosed furnaces (kg/MW-hr basis).

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| Ferroalloys | Organic Compounds | Stationary Sources | 11F | 07C |
| Electric Arc Furnaces | Silicon | Environmental Assessment | | 07B |
| | Manganese | | 13A,13H | |
| Assessments | Waste Water | Particulate | 14B | |
| Dust | Waste Disposal | Baghouses | 11G | |

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# ABSTRACT

This report presents the results of a sampling and analysis project at five ferroalloy plants. The purpose of the study was to determine the amounts of particulate and organic generated during manufacture of several products, the effect of furnace type on the amounts generated, and to determine the amounts of these materials escaping to the environment.

Simultaneous samples, by modified EPA Method 5, were taken before and after the baghouse emission control systems of three open type furnaces producing silicon metal, high carbon ferromanganese, and 50 percent grade ferrosilicon. Simultaneous samples, by modified EPA Method 5, were taken after the primary emission control scrubbers and of fume in the secondary emission control systems and of the scrubber discharge water, by automatic compositing samples, of two semi-enclosed furnaces producing H.C. ferromanganese and 50 percent grade ferrosilicon. Samples were also taken of the influent to and effluent from two plant wastewater treatment systems and groundwater samples around the waste disposal area of one plant.

More organic matter is emitted to the atmosphere than particulate matter. Open furnaces emit as much or more organic to the atmosphere as do semi-enclosed furnaces (Kg/MW-hr basis). Benzo(a)pyrene (BaP) was detected in the emission to the atmosphere from both covered furnaces and from the Si metal furnace. BaP was detected on the solids collected by the particulate capture equipment of all furnaces. Wastewater treatment systems were very effective in removing particulate, organic, and BaP. No metals were extractable (EPA-OSW extraction procedure) from any of the solid wastes in sufficiently high concentrations to classify any of the wastes as hazardous. Groundwater testing at one site showed no leaching of metals or organics.

## TABLE OF CONVERSION FACTORS

| To Convert From | To | Multiply By |
|---|---|---|
| °C | °F | °F = 1.8°C + 32 |
| Meters | Feet | 3.2808 |
| Kg | lbs | 2.2046 |
| Mg | Tons (2000 lb) | 1.1023 |
| Mg | Tons (2240 lb) | 0.9842 |
| mm Hg | inches $H_2O$ | 0.53526 |
| cm Hg | inches Hg | 0.3937 |
| $m^3$ | gallons | 264.17 |
| μg/L | ppb | 1 |
| $dsm^{3+}$ | dscf | 35.315 |
| $mg/dsm^3$ | grains/dscf | 0.000437 |
| Kg/Mg | lb/ton (2000 lb) | 2 |

# ACKNOWLEDGMENT

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RTI also wishes to acknowledge the contributions made by personnel of Entropy Environmentalists, Inc., who carried out the sampling program and frequently worked under adverse conditions. The author also wishes to acknowledge the contributions made by personnel of GCA Corporation who were conducting simultaneous testing at three of the furnaces tested.

The author also wishes to express appreciation to Dr. Robert Handy of RTI under whose direction most of the analytical work was done.

RTI wishes to extend special appreciation to the ferroalloy industry for their cooperation with this study. Special thanks are extended to Mr. George Watson, President of The Ferroalloy Association, and to the management and personnel of Foote Mineral Company, Interlake, Inc., Roane, Ltd., and Union Carbide Corporation. The Union Carbide furnaces tested are now owned by Elkem Metals Company.

# 1.0 INTRODUCTION

Ferroalloys are mixtures of iron and alloying elements which when added to molten iron give it the unique character and properties associated with different grades of steel. The ferroalloy used amounts to about 2 percent of the weight of the finished steel. Thus, compared to the iron and steel industry, the tonnage produced by the ferroalloy industry is small, but is vital.

Ferroalloys are primarily produced in submerged arc electric furnaces. The furnace is typically cylindrical and lined with refractory or carbon bricks. Carbon electrodes extend into the furnace to within a few meters of the bottom. Vertical movement of the electrodes is possible, but they are not used to bore through the charge as in a steelmaking electric arc furnace. Raw materials (coal, coke, woodchips, scrap iron, and ore) are added to the furnace and power is supplied to the furnace through the electrodes. The heat produced by the current flowing through the charge is sufficient to allow the smelting reactions to occur and produce the alloy in a molten state. The alloy is removed intermittently through tapholes in the furnace shell, cooled, and sized for shipment. Power is supplied to the furnace continuously and raw materials are added as needed.

Carbon monoxide rich gases generated by the smelting reactions contain fume from the high temperature region and also entrain finer material contained in the furnace charge. In open furnaces (no top cover) the escaping gases burn on the surface of the charged material. Typically fumes from these furnaces are collected in hoods above the furnace and the particulate matter removed in a baghouse but wet scrubbers are used on a few furnaces. For covered-type (semi-enclosed and sealed) furnaces on which covers fit tightly over the furnace top and raw materials are added either through annular spaces around the electrodes (semi-enclosed) or through sealed chutes (sealed) little combustion normally occurs under the cover. The space under the cover is evacuated through a scrubber. The cleaned CO rich gas is then either flared or used as a fuel. Fumes escaping around the electrodes (secondary emissions) are captured by a hood above the furnace and either discharged directly to the atmosphere or cleaned in a baghouse. A more detailed description of ferroalloy furnaces and their pollution control equipment can be found in references[1,2].

In 1974 EPA published two volumes[2] containing background information which gave justification for New Source Performance Standards (NSPS) for particulate emissions from ferroalloy furnaces. The NSPS for ferroalloy production facilities was proposed October 21, 1974 and promulgated May 4, 1976. Emissions data indicated sealed furnaces could achieve the lowest emissions level. However, the Administration determined that restricting the industry to this process could ultimately limit product flexibility and possible decrease intercorporate competition that outweigh the incremental benefits of the additional reduction in air pollution. The NSPS was therefore set at a level which could be met by well controlled open furnaces. The Office of Research and Development (ORD) undertook a technical and economic feasibility study[3] which concluded that exclusive use of sealed furnaces would, indeed, restrict product flexibility.

ORD also initiated a comparison of the emissions, other than particulate, produced by open and covered (both semi-enclosed and sealed) furnaces. Emphasis was placed on the relative levels of organic compounds in the emissions known or suspected to be carcinogens.

The first step in the emissions comparison was more in-depth analysis of selected samples gathered during NSPS development. Comparisons were made of polynuclear organic matter (POM) content of emissions samples from open and sealed furnaces producing the same alloy. These screening tests indicated the sealed furnace emission prior to combustion of the CO contained as much as 27 percent POM whereas the open furnace emissions contained less than 26 ppm. In all known cases, the cleaned CO rich gas from sealed furnaces is combusted either by flaring or by using it as a fuel. One would expect most of the POM to be destroyed in the process. However, the high levels indicated before combustion pointed towards the need for additional data.

Since the NSPS background samples had not been collected with organic analysis in mind and, in any case were, at this point, several years old the decision was made to pursue obtaining new samples using newly developed organic sampling protocols.

The only modern sealed ferroalloy furnace in North America is located in Beauharnois, Quebec, Canada. It alternately produces FeMn and SiMn in a 82 MVA furnace. Following a number of delays, the furnace emissions were sampled in August 1977. The complete results were published in February 1979.[4]

The sampling contractor encountered several problems during the field test with the result that only two valid samples were obtained-- one at the scrubber inlet while producing FeMn; the other at the scrubber outlet while producing SiMn. The inlet test (on FeMn) showed very high POM concentrations (633 $mg/m^3$) while the outlet test (on SiMn) showed a substantially lower amount (4.2 $mg/m^3$). Corresponding particulate concentrations were 68,000 $mg/m^3$ and 64 $mg/m^3$, respectively. The earlier sealed furnace tests, on a similar unit in Norway, indicated outlet POM/particulate ratios of 0.27 and 0.03 for FeMn and SiMn production, respectively.

The only conclusions which could be drawn from the Beauharnois tests were that (1) scrubber outlet POM/particulate ratio for SiMn production was of the same order as the Norwegian test, and (2) FeMn produced in a sealed furnace generates a significant amount of POMs. Further sampling and analysis was required to answer questions such as POM generation rates as a function of furnace type and alloy produced, POM control efficiencies of the gas cleaner, and POM destruction efficiency in the flare.

As a consequence of these findings, IERL proceeded with a Level 1[5] environmental assessment of the industry. Level 1 is designed to yield information on a wide variety of inorganic and organic species within an accuracy of 1/3 to 3 times the actual concentration of that specie in the stream sampled. That study[6] strongly indicated that covered furnaces generate significantly more organic material on a megawatt of furnace capacity basis than do open furnaces and that the organic generated contained several known and suspected carcinogens. The study did, however, find evidence of significant amounts of organics in the fume generated by open furnaces. Unfortunately, the study, although calling attention to the possibility, did not answer the question as to whether these materials escaped into the environment.

The purpose of the present study was to determine the amounts of particulate and organic generated by various ferroalloy furnaces and to determine the amounts of these materials escaping to the environment. To accomplish this objective, sampling was undertaken at five plants, one furnace at each plant. Stack sampling was done following EPA Methods 1-5 (see Appendices) wherever possible. The furnaces tested included two covered types, one producing 50 percent ferrosilicon and one producing standard ferromanganese and three open types producing, respectively, silicon metal, standard ferromanganese, and 50 percent ferrosilicon. Throughout this report the term covered furnace means the semi-enclosed type unless specifically stated otherwise.

The reader should be aware that in some cases test runs were made which do not meet all criteria of EPA Methods 1-5. Considering that the purpose of the study is research and not enforcement, the emphasis was on obtaining the best data possible without expending great sums of money on construction of facilities (baghouse exhaust stacks, for example) that comply exactly with these criteria.

The report also makes frequent reference to New Source Performance Standards (NSPS). No furnace in the industry is currently subject to these requirements and few, if any, of the capture facilities were built to meet these requirements. The comparison is made this way to provide uniformity (i.e., rather than using individual state regulations).

Simultaneously with the testing described in this report, GCA Corporation conducted testing to determine particulate size distribution before and after the capture equipment. Because of the small duct sizes used for the scrubbers associated with covered furnaces, GCA's testing was limited to the open furnaces. RTI provided GCA with the Method 5 total particulate results for use in their calculations. GCA's results are in a separate report.

# 2.0 SUMMARY

In this project, environmental data were collected for five furnaces. Each test period lasted less than five days. It should be recognized, therefore, that the data are based on a limited test program and represent the performance of individual systems under specific operating conditions. Frequently throughout this report, especially when comparisons are made, the data are used to represent typical performance of similar furnaces producing similar products. These statements are more properly indicators of trends and undue significance should not be attached to numerical ratios.

An effort has been made to use sufficiently specific language that mistaking data taken before capture devices for actual emissions to the environment is unlikely. The term "generated" is used to refer to materials entering a collection or control device. The term "emitted" is used only to refer to material actually entering the atmosphere.

## 2.1 OBJECTIVE OF STUDY

Subsequent to EPA testing of ferroalloy furnaces for development of New Source Performance Standards (NSPS), EPA conducted two screening studies[4,6] to determine the potential for emission of pollutants other than particulate. The purpose of those studies was not to produce highly accurate, quantitative data, but rather to indicate the magnitude of many organic and inorganic species generated and potentially emitted. The most comprehensive of these was an EPA-IERL/RTP Level 1 study[6] which involved tests of six furnaces at three plants. That study indicate that covered furnaces generated significantly more organic in terms of kilograms of emissions per megawatt of furnace power (Kg/MW-hr) than did open furnaces and that several known and suspected carcinogens were present in this organic matter.

The present study was focused by the results of the Level 1 study. The objective of the study was to determine, using accurate, quantitative techniques, the rates at which particulates and organics, particularly benzo(a)pyrene (BaP), are generated by and emitted from ferroalloy furnaces. Although data were obtained for individual furnaces, the intent was to provide sufficient information to allow a comparison of the relative generation and emission rates of open and covered furnaces producing similar products.

## 2.2 FURNACES SELECTED FOR TESTING

A detailed listing of furnace types, power ratings, products normally produced, and type of emission capture systems was obtained from The Ferroalloy Association in May 1980. These data were analyzed and are presented in Table 19, Section 5. This information was used to prioritize the products, furnace types, and pollution capture equipment types to be tested, consistent with the overall objectives stated above and the funding limitations of the study.

Since NSPS is written in terms of Kg/MW-hr, the total MW rating of furnaces producing a particular product was chosen as the ranking factor. Using this ranking criteria, silicon metal is the dominant product with 23.5 percent of installed capacity. Furnaces producing all grades of ferrosilicon (FeSi) comprised 39 percent of installed capacity with furnaces normally producing only 50 percent FeSi accounting for 37 percent of FeSi capacity or 14.7 percent of industry capacity. Ferrochrome (FeCr), silicomanganese (SiMn), and ferromanganese (FeMn) ranked next with, respectively, 10.5, 9.7, and 7.0 percent of installed capacity. However, based on contacts with industry personnel at the time furnace selections were being made, production of FeCr was significantly below capacity and almost exclusively in open furnaces and the only covered furnace in the United States producing SiMn was not operating. This made comparison of these products in both open and covered furnaces virtually impossible. The desired comparison could, however, be made for FeMn production.

In addition to the above criteria, other criteria used in furnace selection were: the source was reported (or appeared) to be well controlled; the site was amenable to testing (segregated ductwork, etc.).

Based on knowledge gained from previous studies, industry contacts, and on-site visits, the furnaces listed in Table 1 were selected for testing.

## 2.3 SAMPLING METHODOLOGY

Particulate sampling was done following EPA Methods 1-5 (see Appendix for details) where possible. These methods result in quite accurate gas flow rate and particulate concentration determinations. A cartridge filled with XAD-2 resin was installed in the sampling train to capture organics. This resin is recognized as an efficient organic trapping material.

Samples were taken with this equipment, at all open type furnaces, in the duct between the furnace and before any pollution capture equipment. Simultaneously, samples were taken of the baghouse exhausts through ports placed in the baghouse walls between the top of the bags and the roof monitor. Although the baghouse exhaust samples were obtained at substantially greater than isokinetic rates, this should have little, if any, effect on particulate concentrations determined because of the anticipated small mean aerodynamic particulate diameters. A minimum of 3, up to a maximum of 6 samples, were taken at each location.

For both covered furnaces, samples were taken simultaneously of the cleaned gas discharged by the scrubbers, the fume collected by the secondary fume hood, and the scrubber discharge water (automatic, compositing water sampler). Samples could not be obtained of the fume in the duct between the furnace and the scrubber because of water sprays in this area. At the covered 50 percent FeSi furnace, samples were also taken simultaneously of the baghouse inlet and outlet to determine the baghouse efficiency for capture of secondary fumes. The efficiency thus determined was used in calculating total emissions from the furnace. Other samples collected at the plants included:

1. Dust collected by the baghouse (for all except the covered FeMn furnace which uses no baghouse).

TABLE 1. FURNACES TESTED

| Product | Furnace Type | Furnace Number | Power Rating, MW | Capture Method | Company | Location |
|---|---|---|---|---|---|---|
| Silicon Metal | Open | 2 | 17 | Baghouse | Interlake, Inc. | Selma, AL |
| 50% FeSi | Open | 2 | 35 | Baghouse | Foote Mineral Co. | Graham, WV |
| 50% FeSi | Covered | 23 | 45 | Scrubber-Baghouse for Secondary Fume | Union Carbide Corp. | Ashtabula, OH[a] |
| FeMn | Open | 3 & 4 | 9 & 10 | Common Baghouse | Roane, Ltd. | Rockwood, TN |
| FeMn | Covered | 17 | 8 | Scrubber-Secondary Fume Uncontrolled | Union Carbide Corp. | Marietta, OH[a] |

[a] Plants at these locations now owned by Elkem Metals Company.

2. Wastewater treatment pond influents and effluents, obtained with automatic compositing water sampler, at the two plants (both covered furnaces) using this treatment method.

3. Groundwater, up-gradient and down-gradient of the entire landfill and wastewater pond area, at one plant (Ashtabula, OH).

Section 5 of this report and the individual test descriptions contain more detail on sample acquisition methods.

## 2.4 ANALYSIS METHODOLOGY

Particulate captured by the filter and probe of the sampling train was recovered, dried, and weighed to ± 0.1 mg. The particulate collected, the impinger solutions, and the XAD-2 resin were extracted with methylene chloride for recovery of organic compounds. An aliquot of the extract was evaporated at room temperature. The dry residue recovered was weighed and is reported here as total organics. This method is equivalent to Level 1[5] Grav organics. This method recovers the high boiling point (>300°C) organics only. The extracts were analyzed for BaP by thin layer chromatography (TLC) with quantification by fluorescence detection techniques. Selected samples were also analyzed by gas chromatography- mass spectrography (GC-MS) for quantification of other polynuclear aromatic organic compounds.

All water samples were filtered to determine particulate concentration and both solid and aqueous components extracted to recover organics and analyzed as above. The extracts were analyzed by TLC for quantification of BaP. Wastewater treatment pond samples were also analyzed by EPA approved methods for compounds designed by EPA as priority pollutants.

All baghouse dust samples collected were analyzed by atomic absorption spectroscopy for metals on EPA's priority pollutant list. The dusts were also extracted following EPA's Office of Solid Waste procedures and the extract analyzed for the metals cited above.

## 2.5 PARTICULATE GENERATED BY FURNACES

Given in Table 2 are the results of tests made to determine the amount of particulate generated by each furnace tested. The results are the averages of several (3-6) separate tests for each furnace. For the open furnaces, these tests were made in the ducts between the furnace hood and the

TABLE 2. PARTICULATE MATTER GENERATED BY FURNACES TESTED

| Product | Furnace Type | Average Load During Tests MW-hr/hr | Kg Generated per Hour | Kg Generated per MW-hr | Range Kg/MW-hr | Kg Generated per Mg Feed | Kg Generated per Mg Alloy |
|---|---|---|---|---|---|---|---|
| Si Metal | Open | 17.3 | 567.2 | 32.55 | 18.27-52.47 | 77.5 | 436 |
| 50% FeSi | Open | 32.1 | 234.8 | 7.36 | 5.67- 9.74 | 15.72 | 34.87 |
| 50% FeSi | Covered | 43.0 | 307.0 | 7.14 | 4.81-10.55 | 15.7 | 32.3 |
| HC FeMn | Open | 20.0 | 94.8 | 4.75 | 3.01- 6.64 | 5.73 | 14.2 |
| HC FeMn | Covered | 6.8 | 15.5 | 2.37 | 1.18- 3.80 | 2.09 | 6.21 |

pollution capture equipment. For the covered furnaces, the data are the sum of particulate captured by the scrubber, particulate passing through the scrubber, and particulate collected by the secondary fume hood. The data include, therefore, all fume generated by the furnace proper but include varying amounts of tapping fume. It does not include fume generated by pouring the molten alloy into chills for alloy solidication or from crushing and sizing operations.

Complete capture of tapping fume was observed only at the open furnace producing 50 percent FeSi. Tap fume collection at the silicon metal furnace was estimated to be about 60 percent. Less than 50 percent of the tapping fume was collected by the open FeMn furnace. About 80 percent of the covered 50 percent FeSi furnace tapping fume was collected. Less than 10 percent of tapping fume from the covered FeMn furnace was collected.

Given in the table are the average power inputs to the furnaces during the testing. The loads are 105, 92, 96, 105, and 85 percent of the design ratings of the furnaces, respectively for Si metal, open 50 percent FeSi, covered 50 percent FeSi, open FeMn, and covered FeMn. Thus, generally, the furnaces were operated at near rated levels.

Also given in the table are the amounts of particulate generated per furnace operating hour. These results are influenced by both product type and furnace size. A more informative measure of fume generation is given in the three columns wherein the fume generation rate is expressed in terms of Kg per MW-hr of power consumed, per Mg of raw materials fed, and per Mg of alloy produced. Expressed in these ways, the data are essentially independent of furnace size and allows more definitive comparisons based on product type and furnace type.

When compared on any of these three bases, there is an obvious and substantial difference among the products produced. The furnace producing Si metal generated over four times as much particulate per MW-hr of power consumed than did the 50 percent FeSi furnaces and over 6 times as much particulate as the FeMn furnaces. When compared on the basis of raw material fed, the Si furnace generated about five times as much particulate as the 50 percent FeSi furnaces and over 13 times as much as the FeMn furnaces. When compared on the basis of alloy produced, the silicon furnace generated over

12 times as much particulate as did the FeSi furnaces and over 30 times as much as the FeMn furnaces.

The data also allow a comparison of similar products produced in different furnace types. The data suggest there is little difference in the fume generation rates between the two furnace types producing 50 percent FeSi. The open furnace data are based on the average of five tests and the covered furnace data on three tests. Equivalence of fume generation rate is reflected in all three measures of operating characteristics: Kg fume per MW-hr, per Mg feed, and per Mg alloy produced.

Comparison of the data for the FeMn furnaces, however, indicates a significant variation in the fume generation rates for the two furnaces. The covered furnace generated about 1/2 as much fume as did the open furnace, based on the above three measures of operating characteristics. The open furnace results are the averages of six tests while the covered furnace data are the averages of five tests. The open furnace tests were made on the combined fume from two furnaces, one rated at 9 MW and one rated at 10 MW. The following should be considered as possibly affecting this comparison. The covered furnace was operating at about 85 percent of its rated capacity whereas the open furnaces were operated at about rated capacity. Furthermore, in the process observers opinion, the raw material fed to the covered furnace appeared to contain less fine material than that fed to the open furnaces. Both factors may have led to lower generation of fume by the covered furnace.

Table 2 also contains the range of particulate generation rates determined in the tests (Kg/MW-hr). It is obvious that there is substantial variability in the data. The process observers notes were examined to see if any activity at the furnace could explain the variability. Visual observations indicated that fume generation increased during periods of tapping, raw material addition, stoking, and furnace blows. However, only furnace blows seemed to have a major effect on the fume generation rate. Although some furnace blows (jets of extremely hot gas emanating from the area around the electrodes and frequently ejecting raw material and molten material upward toward the hood offtake ducts and occasionally even out onto the furnace room floor) were observed for all furnaces tested, these were more severe for the silicon furnace and is the likely explanation for the wide range in fume generation observed. It is well known that furnaces producing silicon metal are subject to severe blows and this is the primary reason that this alloy is not produced in covered furnaces.

## 2.6 PARTICULATE EMITTED TO ATMOSPHERE BY FURNACES TESTED

Given in Table 3 are the results of tests made to determine the amount of particulate matter emitted to the atmosphere. For the open furnaces, these data are the averages of tests (3-5) made in the outlet side of the baghouse compartments. The actual flow rates in the baghouse outlets were not measured. They were calculated based on ambient air temperature, outlet gas temperature, and inlet flow rate and temperature. The outlet flow rate for the open FeSi furnace was estimated based on engineering judgment since an error was discovered in the inlet temperature reading. Data for the covered furnaces are the sum of particulate in the gas exiting the scrubber capturing fume removed from beneath the cover and particulate emitted from the secondary fume capture system which handles fume escaping the furnace cover. A baghouse is used to capture these fumes from the FeSi furnace. There is no capture equipment installed for collection of secondary fume generated by the covered FeMn furnace.

Two sets of results are given for both covered furnaces. For the FeSi furnace, the baghouse particulate collection efficiency was determined to be 73.6 percent. The larger numbers given reflect applying this efficiency to the mass of particulate entering the baghouse. The smaller numbers in parentheses reflect the same calculation assuming a baghouse particulate capture efficiency of 98 percent which the authors believe is a more accurate emission rate when the baghouse is operating under normal, full load conditions (see Section 9.4.2 for more complete discussion). For the FeMn furnace the larger numbers are those actually measured. The numbers in parentheses are presented for comparison only and assume installation of some device with a 98 percent particulate capture efficiency.

The covered FeSi furnace had the highest actual emission to the atmosphere of all furnaces tested and the open FeMn the lowest. If, however, capture of secondary fume from the covered furnaces had been 98 percent, the

TABLE 3. PARTICULATE MATTER EMITTED TO ATMOSPHERE BY FURNACES TESTED

| Product | Furnace Type | Average Load During Tests MW-hr/hr | Kg Emitted per hour | Kg Emitted per MW-hr | Range Kg/MW-hr | Kg Emitted per Mg Feed | Kg Emitted per Mg Alloy |
|---|---|---|---|---|---|---|---|
| Si Metal | Open | 17.4 | 21.2 | 1.22 | 0.18 -2.9 | 2.87 | 16.5 |
| 50% FeSi | Open | 31.9 | 6.29 | 0.197 | 0.12 -0.27 | 0.37 | 0.92 |
| 50% FeSi | Covered | 43.0 | 32.5[a]<br>(4.6)[a] | 0.755<br>(0.11) | 0.38 -1.37 | 1.66<br>(0.24) | 3.42<br>(0.49) |
| HC FeMn | Open | 19.9 | 1.54 | 0.078 | 0.031-0.16 | 0.085 | 0.236 |
| HC FeMn | Covered | 6.8 | 4.93[a]<br>(0.16)[b] | 0.785<br>(0.025) | 0.086-2.0 | 0.76<br>(0.023) | 2.06<br>(0.071) |

[a] First set of numbers reflect a baghouse capture efficiency of 73.6 percent. Numbers in parentheses assume 98 percent capture efficiency.

[b] First set of numbers reflect actual measured emissions. Numbers in parentheses are for comparison purposes only and assume installation of a device on the secondary fume system with a 98 percent capture efficiency.

silicon furnace would have had the highest emissions and the covered FeMn the lowest. When furnace size is effectively eliminated as a variable by calculating the emissions on a Kg per MW-hr, per Mg raw material, or Mg alloy produced, the silicon furnace has the highest emission rate. The two covered furnaces are intermediate and the open FeSi and FeMn furnaces lowest. Emission rates for both covered furnaces are significantly higher than their open furnace counterpart because of the lack of efficient particulate removal from the captured secondary fumes from the covered furnaces.

New Source Performance Standards (NSPS) for ferroalloys are 0.45 Kg/MW-hr for silicon metal and ferrosilicon (50 percent or greater Si) and 0.23 Kg/MW-hr for FeMn and lower grades of FeSi. *These standards are not applicable to any furnace tested in this project or to any other currently operating furnaces*. Using NSPS as a guideline for discussion purposes only, it can be seen that the average particulate emissions from the silicon producing furnace and both covered furnaces exceeded these standards. At least one test on all furnaces, except the covered FeSi furnace, gave emission rates below NSPS levels. Some of the factors which may have contributed to the variability of the observed emission rates are discussed below.

Table 4 gives the overall test average collection efficiency of the capture device in use. As can be seen, the baghouses on the open furnaces

TABLE 4. EFFICIENCY OF CAPTURE DEVICES FOR PARTICULATE MATTER

| Product | Furnace Type | Baghouse Efficiency, % | Scrubber Efficiency, % |
|---|---|---|---|
| Si Metal | Open | 96.3 | |
| 50% FeSi | Open | 97.2 | |
| 50% FeSi | Covered | 73.6 (98) | 98.7 |
| HC FeMn | Open | 98.4 | |
| HC FeMn | Covered | | 99.4 |

averaged between about 96 and 98 percent particulate capture. The scrubbers on the covered furnaces averaged about 98 percent capture efficiency. Capture of secondary fumes generated by the covered furnaces was, however, poor. We cite this at this point because capture equipment efficiency is a major variable affecting emission rates.

The 96 percent efficiency for the silicon metal furnace baghouse is the average of five runs with efficiencies ranging from about 86 to over 99 percent. For the first three runs made at this facility, the baghouse efficiency averaged 98.9 percent and the average emissions were less than the NSPS guidelines. For the last two tests, both done on the same day, the baghouse efficiency averaged only 90 percent. Bag failure occurred in several compartments on that day; none of the compartments were being tested at the time of failure. After reviewing the data, it is our conclusion that several, perhaps many, bags had begun to leak, but not completely failed, including some in the compartment being tested, by this third day of testing. Since the plant reported that bag failure is a constant, and expensive problem, we do not consider the results obtained to be atypical. It seems likely, considering the results of the first three tests, that if the excessive rate of bag failure could be corrected and tap fume control improved the system would meet NSPS. The plant has attempted to solve these problems but, as yet, has not been successful. In fact, if this had been a compliance test, it is highly likely that the particulate results obtained on the last test day would have been rejected and not included in the average.

No evidence of bag failure or other unusual occurrences were noted during testing of the baghouse on the FeSi and FeMn furnaces. Maintenance requirements on the baghouses were considerably less than for the silicon furnace baghouse. In our opinion, the principal cause of the variability in emission rates determined for these two furnaces is likely due simply to the variability in the capture efficiency among individual baghouse compartments.

The variability in emission rate for both covered furnaces is due almost entirely to the secondary fume control systems. Fume from the secondary system of the covered FeSi furnace is controlled by a baghouse that also controls fume from a large open furnace. The open furnace was not operating during the tests but ambient air from this area was being drawn into the baghouse. The capture efficiency of the baghouse under these severely underloaded conditions was only 73.6 percent. Secondary fume from the covered FeMn furnace exhausts directly to atmosphere; no capture equipment in use. Emissions from this source are determined by raw material quality and by controlling furnace operation such that the mix seal is not broken or furnace "blows" (gas jets blowing past the seals) do not occur. Since perfect stability of the furnace cannot be expected, it is not surprising that there is variability in the emission rates.

Included in Table 3 are estimates of the covered furnace emission rates assuming 98 percent control of secondary fumes. This is probably a good estimate for the covered FeSi furnace when its baghouse is operating under normal, full load conditions. Under this assumption both furnaces would have had emission rates less than the NSPS. Of course obtaining this degree of control for the FeMn furnace would require a change in operating procedures or installation of appropriate capture equipment.

Briefly summarizing the particulate results, on a Kg per MW-hr basis generation rates decrease in the order: Si metal, 50% FeSi, and HC FeMn. There appears to be no difference in the particulate generation rates for the open and covered furnaces producing 50% FeSi. There is a difference in the particulate generation rates for the two furnace types producing HC FeMn but this may be due to the particular operating conditions for the covered furnace during testing. Emissions from three of the five furnaces exceeded the NSPS. In one case this occurred because of a lack of appropriate capture equipment. In a second case, this was probably a result of a serious underload condition at the baghouse due to one furnace, normally exhausting to this baghouse, not being in operation. In the third case, the excess emissions were caused by deterioration of baghouse performance during the test period.

## 2.7 ORGANIC MATTER GENERATED BY FURNACES

Given in Table 5 are the results of tests made to determine the amount of organic generated by each furnace tested. The data were generated by analyzing extracts of samples obtained during determination of particulate generation rates (see Section 2.5).

TABLE 5. ORGANIC MATTER GENERATED BY FURNACES TESTED

| Product | Furnace Type | Average Load During Test MW-hr/hr | Generated per hour, Kg | Generated per MW-hr, Kg | Range Kg/MW-hr | Generated per Mg Feed, Kg | Generated per Mg Alloy, Kg |
|---|---|---|---|---|---|---|---|
| Si Metal | Open | 17.3 | 45.7 | 2.64 | 1.29-3.63 | 6.50 | 35.9 |
| 50% FeSi | Open | 32.1 | 22.1 | 0.69 | 0.12-1.18 | 1.3 | 3.2 |
| 50% FeSi | Covered | 43.0 | 71.1 | 1.65 | 1.47-1.78 | 3.63 | 7.48 |
| HC FeMn | Open | 20.0 | 35.6 | 1.78 | 0 -3.37 | 2.30 | 5.32 |
| HC FeMn | Covered | 6.8 | 1.69 | 0.26 | 0.14-0.50 | 0.23 | 0.69 |

Column 4 of this table gives the average amount of organic matter generated per hour by each furnace. The covered FeSi furnace generated the most organic matter per hour, followed by the open Si metal, covered FeMn, open FeSi, and covered FeMn.

More informative measures of organic generation are given in the three columns wherein the organic generation rate is expressed in terms of Kg per MW-hr of power consumed, per Mg of raw material fed, and per Mg of alloy tapped. Expressed in this way, the data are essentially independent of furnace size and allow a more definitive comparison based on product type and furnace type. Compared in these ways, there are significant differences among product types and between furnace types.

Compared on a Kg generated per MW-hr basis, the Si metal furnace generated the most organic. The open FeMn, covered FeSi, open FeSi, and covered FeMn furnaces followed, respectively, in order of decreasing generation rates. There is only one ordering change when the furnaces are compared on the basis of raw material feed rate or rate of alloy production. In decreasing rate of organic generation, the ordering is: Si metal, covered FeSi, open FeMn, open FeSi, and covered FeMn.

Comparison of only the open furnaces in decreasing order of organic generation gives an ordering of Si metal, FeMn, and FeSi for calculation on a MW-hr, Mg raw material, and Mg alloy tapped basis. The reason(s) for this ordering are not apparent to the contractor.

The covered FeSi furnace generates substantially more organic than does the covered FeMn furnace. The products produced in these furnaces are, however, unlikely to be the sole, or even major, cause of the difference observed. Although both furnaces are of covered design, a substantial amount of undercover combustion occurred in the FeMn furnace and little, if any, undercover combustion occurred in the FeSi furnace. The FeSi furnace cover was fairly tightly sealed to prevent undercover combustion because the plant uses the high CO content gas produced as fuel in another plant process. With the present data base, we cannot state the relative ordering if these two products were produced under similar operating conditions. (However, see rationalization in discussion below on comparison of FeMn production in different furnaces.)

The data also allow some comparison of the production of similar products in different type furnaces. No comparison can be made for Si metal, which is produced only in open type furnaces.

The study includes comparison of one open and one tightly covered, but not sealed, furnace producing products of 40-50 percent silicon. The open furnace was producing standard 50 percent FeSi with a nominal Si content of 46-49 percent. The covered furnace was producing a product of 42 percent Si and 6 percent Mn. The Mn was added to the charge as FeMn and not as ore. Thus, slightly less raw material reduction was required in the covered furnace to yield the same weight of finished product. Comparison of the data in Table 5 shows that the covered furnace generated about 2.5 times the organic matter generated by the open furnace, when compared on either a Kg/MW-hr, Kg/Mg feed, or Kg/Mg alloy produced basis. We attribute this difference to the fact that, in an open furnace, the gas burns as it leaves the surface of the raw material charge, whereas, in the covered furnace, the raw gas withdrawn from beneath the cover is not burned. Gases escaping the covered furnace cover burn during blows or when the seal is broken and the cleaned gas discharged by the scrubber is either burned in the lime kiln or flared-- both of the latter occurring downstream of the sample point. Neither furnace is an atypical design for their type.

The study also compares open and loosely covered furnaces producing high carbon FeMn which will be referred to in this report only as FeMn. In this case, the open furnace generated almost seven times as much organic matter as did the covered furnace on a Kg/MW-hr basis. The ratio was even higher when the comparison is based on Kg/Mg feed (factor of 10) or Kg/Mg alloy (factor of 7.7). Note that this is the opposite of results for the FeSi furnaces. The comparison for FeMn is between a fairly typical open furnace and an atypical covered furnace in which substantial undercover combustion of furnace gas was occurring as confirmed by visual observation of fire through openings in the furnace cover, and results of an Orsat gas analysis, (see Section 10.4.1). The results obtained here agree with the results obtained in the previous Level 1 study[6] for a similar pair of furnaces producing FeMn.

The results for the FeMn furnaces suggest that more complete destruction of organic matter can be obtained when the gas is burned with little excess oxygen which probably results in higher flame temperature. It also seems quite likely, based on results for the FeSi furnaces, that if the covered FeMn furnace were tightly covered, it would generate more organic than does the open FeMn furnace. If this were the case, one would expect significantly more organic to be generated in a tightly covered FeMn furnace than a tightly covered FeSi furnace. Conversely, one would expect significantly less organic to be generated by a loosely covered FeSi furnace than a loosely covered FeMn furnace, possibly even less than an open FeSi furnace.

## 2.8 ORGANIC MATTER EMITTED BY FURNACES TESTED

Given in Table 6 are the results for organic matter emitted to the atmosphere. These data were obtained by extracting samples collected during determination of particulate emissions. Two sets of numbers are given for the covered 50 percent FeSi furnace. The first numbers are based on two assumptions. (1) no destruction of organic by the flare which handles gas from the scrubber (valid only when the flare is not operating), and (2) 13 percent capture of organics in the secondary fume baghouse. The latter value is the percent organic adsorbed on the particulate matter. The second numbers given (in parentheses) differ only in that they assumes 100 percent destruction of organic by the scrubber flare, which is likely nearly correct when the flare is operating. All comparisons which follow are based on this second assumption.

Given in the fourth column of the table is the average amount of organic matter emitted per hour by each furnace fume capture system. In order of decreasing emissions, the furnace ordering is: Si metal, covered 50 percent FeSi, open FeSi, open FeMn, and covered FeMn.

More informative measures of the organic emission rates are given in the last four columns, which minimize the effect of furnace size.

Compared on a Kg emitted per MW-hr basis, the Si metal furnace emits over three times as much organic as the second ranked furnace. This is followed, in order, by the open FeMn furnace, both FeSi furnaces and the covered FeMn furnace. The rankings change little when emissions are calculated on the

TABLE 6. ORGANIC MATTER EMITTED TO ATMOSPHERE BY FURNACES TESTED

| Run Number | Furnace Type | Average Load During Test MW-hr/hr | Emitted per hour, Kg | Emitted per MW-hr, Kg | Range MW-hr, Kg | Emitted per Mg Feed, Kg | Emitted per Mg Alloy, Kg |
|---|---|---|---|---|---|---|---|
| Si Metal | Open | 17.4 | 34.3 | 1.92 | 0.92-3.93 | 4.90 | 25.8 |
| 50% FeSi | Open | 31.9 | 15.0 | 0.47 | 0.34-0.56 | 0.89 | 2.2 |
| 50% FeSi | Covered | 43.0 | 26.0[a]<br>(20.2)[b] | 0.60<br>(0.47) | 0.54-0.68 | 1.33<br>(1.04) | 2.74<br>(2.13) |
| HC FeMn | Open | 19.9 | 12.6 | 0.64 | 0.50-0.75 | 0.63 | 1.86 |
| HC FeMn | Covered | 6.8 | 1.0 | 0.15 | 0.11-0.18 | 0.13 | 0.40 |

[a] Assumes no destruction of organic by the scrubber flare and 13 percent capture in secondary fume baghouse.

[b] Assumes 100 percent destruction of organic by the scrubber flare and 13 percent capture in secondary fume baghouse.

bases of raw material fed or alloy produced. The emission ratios among furnaces do change, however.

Returning to comparisons based on a Kg/MW-hr basis, it can be seen that the three open furnaces emit as much or more organic matter than do the covered furnaces. The open furnace rankings in order of decreasing emissions are Si, FeMn, and FeSi. When emission data for these three furnaces are compared to generation data (Table 5), an interesting observation can be made. That is, the percent capture of organics by the baghouse seems to be related to baghouse operating temperature. The percent organic capture was 25, 32, and 65 percent, respectively, for Si, FeSi, and FeMn. The baghouse temperatures, in the same order were about 110°, 90°, and 60°C. Thus, the hotter the baghouse, the lower the organic capture efficiency, conforming to the generally accepted hypothesis.

Comparing similar products manufactured in different types of furnaces on a Kg/Mw-hr basis, it can be seen that emissions from the two FeSi furnaces were essentially equivalent despite the fact that the covered furnace generated about 2.5 times as much organic. This can be attributed to better organic capture in the scrubber than the baghouse. Organic emissions from the covered FeMn furnace were significantly lower than the open FeMn furnace despite the fact that there is no capture device for secondary fumes on the covered furnace. Overall percent capture of organic was, 64 percent for the open FeMn furnace compared to 42 percent for the covered furnace. As discussed in the preceding section, we believe the low organic generation rate by the covered FeMn furnace is due to significant undercover combustion. A similar comparison for Si metal production is not possible since it is produced only in open furnaces.

Given in Table 7 are the overall test average organic matter collection efficiencies of the capture devices in use. As can be seen, the baghouses on the open furnaces vary considerably in the efficiency with which organic matter is captured. We have noted previously that these capture efficiencies seem to be correlated inversely with baghouse operating temperature. That is, the higher the baghouse operating temperature, the lower is the capture efficiency for organics. As noted above, this correlation conforms to theory, however, it may be only coincidental and could simply reflect differences in the types of organic matter generated by the furnaces.

TABLE 7. EFFICIENCY OF CAPTURE DEVICES FOR ORGANIC MATTER

| Product | Furnace Type | Baghouse Efficiency, % | Scrubber Efficiency, % |
|---|---|---|---|
| Si Metal | Open | 24.9 | |
| 50% FeSi | Open | 32.1 | |
| 50% FeSi | Covered | 13 | 87.9 |
| HC FeMn | Open | 64.6 | |
| HC FeMn | Covered | | 64.5 |

Organic capture efficiency of the baghouse secondary fume from the covered FeSi furnace was lower than for the other baghouses. This is likely due to a higher percentage of volatile organics in the secondary fume. No capture equipment is used on secondary fume from the covered FeMn furnace.

The scrubbers captured a greater percentage of the organic matter than did the baghouses. The lower result obtained for the FeMn furnace is likely due to lower inlet organic concentration and to scrubber type.

## 2.9 BENZO(a)PYRENE (BaP) GENERATED BY FURNACES

Given in Table 8 are the data relating to BaP generated by the furnaces. Column 4 of the table gives the amount of BaP generated per hour by each furnace. Note that data on BaP are given in grams rather than Kg used in previous tables. The tightly covered 50 percent FeSi furnace is by far the largest BaP generator, almost 500 times as much as the second ranked furnace. Following in decrease order of BaP generation are Si metal, covered FeMn, open FeSi, and open FeMn.

More informative measures of the BaP generation rates are given in the last four columns of the table. Data in these columns are essentially independent of furnace size. In terms of grams BaP generated per MW-hr, the covered FeSi furnace still has, by far, the largest generation rate. The Si metal and covered FeMn rank second, with essentially equal rates. BaP generation by the open FeSi furnace was about an order of magnitude less than the second ranked furnaces. BaP generated by the open FeMn furnace was below

TABLE 8. BaP GENERATED BY FURNACES TESTED

| Product | Furnace Type | Average Load During Test MW-hr, gms | Generated per hour, gms | Generated per MW-hr, gms | Range gms/MW-hr | Generated per Mg Feed, gms | Generated per Mg Alloy, gms |
|---|---|---|---|---|---|---|---|
| Si Metal | Open | 17.3 | 0.36 | 0.021 | 0 -0.046 | 0.050 | 0.28 |
| 50% FeSi | Open | 32.1 | ∿0.082 | ∿0.003 | 0 -0.012 | ∿0.005 | ∿0.014 |
| 50% FeSi | Covered | 43.0 | 175 | 4.06 | 3.1-5.4 | 8.92 | 18.4 |
| HC FeMn | Open | 20.0 | 0 | 0 | 0, all runs | 0 | 0 |
| HC FeMn | Covered | 6.8 | 0.15 | 0.022 | 0.01-0.035 | 0.018 | 0.058 |

the detection limit of the methods used. As will be discussed later, analysis of the dust captured by the baghouse did show some BaP, which indicates the furnace does generate some small amount of BaP.

The relative rankings of the furnaces when compared on the basis of raw material fed or alloy produced is the same as given for the grams/hour basis above. The ratios among furnaces does change, however.

Comparing only the open furnaces, the ranking in order of decreasing generation rate is: Si metal, FeSi, and FeMn. The rankings are the same on all bases calculated. Although the ratios of BaP generation rates among furnaces are substantial, the total amount generated would seem to be quite small.

Comparing BaP generated by the covered furnaces, it is obvious that the tightly covered FeSi furnace generated nearly 200 times more BaP than did the loosely covered FeMn furnace (MW-hr basis). The relative amounts of BaP generated is substantially different from the relative organic generation rates which differed by a factor of about 20. Thus, one would be led to believe either that a tightly covered FeMn furnace would generate less BaP than a tightly covered FeSi furnace or that the undercover combustion occurring in the FeMn furnace is more effective in either preventing the formation of or destroying BaP than organics in general. We tend to believe that the latter is the case (see below).

Comparisons can also be made for similar products produced in different furnaces. For FeSi BaP generated by the covered furnace was about 1400 times as great as that generated by the open furnace (MW-hr basis). This is substantially greater than the 2.5 ratio found for the organic generation rates between these furnaces. This tends to imply, as noted in the discussion above, that under the conditions at which these furnaces operate, the combustion occurring either effectively prevents formation of BaP or destroys it at a much greater rate than other organics formed.

Comparison of the two furnaces producing FeMn shows similar, although not as dramatic, results. BaP generated by the open furnace was below the detection limits of the methods used. A small amount of BaP was found in fume generated by the covered furnace, despite the fact that the covered furnace actually generated less organic than did the open furnace. This issue is clouded by the fact that this covered furnace operates with significant undercover combustion which is not generally true for covered furnaces.

## 2.10 BaP EMITTED BY FURNACES

Given in Table 9 are the results for BaP emitted to the atmosphere from the capture systems of the furnaces tested. Two sets of numbers are given for the covered FeSi furnace. The first numbers are based on two assumptions: (1) no destruction of BaP in the scrubber flare (valid only when the flare is not operating), and (2) 73.6 percent capture of BaP in the secondary fume by the baghouse. The latter value is the same as particulate capture efficiency under actual test conditions.) The second number given (in parentheses) assumes 100 percent destruction of BaP in the scrubber flare and 79 percent capture by the secondary fume baghouse. This latter value is the percentage BaP adsorbed on the particulate at 121°C. We consider the second numbers to more accurately reflect emissions from the furnace. All comparisons which follow are based on the second assumption.

The fourth column of data gives the measured emissions to the atmosphere from the furnaces. Only three of the five furnaces had detectable BaP emissions. Emissions, in grams/hour, from the covered FeSi furnace were the highest of all furnaces tested. However, with the flare operating and baghouse performance normal for the covered FeSi furnace, the relative ranking of furnaces in decreasing order of BaP emissions is: Si metal, covered FeSi, and covered FeMn when calculated on the three bases which remove the effect of furnace size. No BaP emissions were detected from the open FeSi or open FeMn furnaces.

Of the three open furnaces, only the Si metal had any measurable BaP emission. BaP was detected in only one of the three valid runs on this furnace. The average BaP emission was 0.21 $\mu g/m^3$. This corresponds to a total BaP emission from this furnace of less than 0.2 grams per hour (g/hr).

Both covered furnaces had detectable amounts of BaP in their emissions to atmosphere. The actual mass of BaP emitted is, however, very small. The covered FeSi furnace emits 0.24 g/hr BaP, the covered FeMn furnace $6 \times 10^{-4}$ g/hr.

TABLE 9. BaP EMITTED TO ATMOSPHERE BY FURNACES TESTED

| Product | Furnace Type | Average Load During Test MW-hr, hr | Emitted per hour, gms | Emitted per MW-hr, gms | Range gms/MW-hr | Emitted per Mg Feed, gms | Emitted per Mg Alloy, gms |
|---|---|---|---|---|---|---|---|
| Si Metal | Open | 17.4 | 0.14 | 0.008 | ND-0.24 | 0.018 | 0.11 |
| 50% FeSi | Open | 31.9 | ND[c] | ND | ND, all runs | ND | ND |
| 50% FeSi | Covered | 43.0 | 1.01[a]<br>(0.24)[b] | 0.024<br>(0.006) | 0.022-0.026 | 0.053<br>(0.012) | 0.11<br>(0.030) |
| HC FeMn | Open | 19.9 | ND | ND | ND, all runs | ND | ND |
| HC FeMn | Covered | 6.8 | 0.0006 | 0.0001 | ND-0.0003 | 0.00005 | 0.0002 |

[a] Assume zero percent destruction of BaP in scrubber flare and 73.6 percent capture in secondary fume baghouse.

[b] Assumes 100 percent destruction of BaP in scrubber flare and 79 percent capture in secondary fume baghouse.

[c] ND means not detected.

Comparing BaP emission from similar products made in different furnace types, it can be seen that both covered furnaces emitted more BaP than did their companion open furnace. The difference is greater for the FeSi furnaces. The covered FeSi furnace generated about 1400 times as much BaP as did the open FeSi furnace. The scrubber on the covered furnace captured over 99.9 percent of the BaP in the scrubber inlet gas. The BaP is not destroyed, however, and eventually ends up in the landfill. Given in Table 10 are the overall average test results for BaP collection efficiencies of the capture devices in use.

TABLE 10. EFFICIENCY OF CAPTURE DEVICES FOR BaP

| Product | Furnace Type | Baghouse Efficiency, % | Scrubber Efficiency, % |
|---|---|---|---|
| Si Metal | Open | 61.1 | NA |
| 50% FeSi | Open | 100 | NA |
| 50% FeSi | Covered | 73.6 (79)[a] | 99.6 |
| HC FeMn | Open | ?[b] | NA |
| HC FeMn | Covered | NA[c] | 99.3 |

[a] The first number given is the same as the measured particulate collection efficiency. The number in parentheses is the estimated capture efficiency under normal full load conditions at the baghouse.

[b] BaP was not detected in either inlet or outlet samples.

[c] Not applicable.

The scrubbers on the covered furnaces were very effective in capturing BaP. Essentially all of the BaP in the scrubber discharge water was adsorbed on the suspended solids.

## 2.11 WASTEWATER TREATMENT

The two plants at which the covered furnace tests were conducted use wastewater treatment systems to treat the process discharge. Composite samples of these waters were taken, before and after treatment, and analyzed for priority pollutants.

At Union Carbide's Ashtabula plant, the untreated water going to the wastewater treatment system pond inlet includes scrubber discharges from the covered FeSi furnace, the calcium carbide furnaces, the coke dryer, and the lime kiln. The plant also slurries dust collected by the various baghouses including furnace secondary air pollution controls and the alloy crusher and discharges this slurry to the waste treatment ponds. Thus, the pond inlet water sample includes both primary and secondary fumes from covered FeSi and $CaC_2$ furnaces, alloy crushing, coke drying, and fume from calcining lime (CO gas from the covered furnaces is used as a fuel in the kiln). The water discharged to the pond would also normally include fume from an open type FeSi furnace, however, during these tests that furnace was not operating.

The wastewater treatment system consists of four ponds (see Figure 12, Section 9). Scrubber water from furnace No.20 operations enters pond 4B. All other wastewater enters pond 4A. Most solids contained in these streams settle out in these ponds and are occasionally dredged out and placed in landfill 3A immediately south of the ponds. The clarified water from ponds A and B flows into small pond 4C where it is chlorinated. The chlorinated water flows into final pond 4D, which provides contact time and final solids removal, before being discharged into Lake Erie.

The wastewater treatment management is somewhat different at Union Carbide's Marietta plant (see Figure 18, Section 10). Water from the electrolytic facilities is oxygenated (UNOX$^R$ system). This water, which has an oxygen residual, is mixed with water from the scrubbers on the submerged arc furnaces. The combined wastewater is discharged into a large (about 100 acres) pond system. The solids which settle out here are dredged out and landfilled. Clarified water from the pond overflows into the river.

At both plants composite samples were taken using an automatic sampler of both the inlet to and exit from the wastewater ponds. The samples were homogenized and split in the RTI laboratory. One portion of the sample was filtered for suspended solids determination and the filtrate and solids further analyzed for organics and BaP. A second portion of the sample was analyzed by Stewart Laboratories, Inc. for EPA designated priority pollutants. A third portion was used for tests discussed in the following section on solid wastes.

Given in Table 11 are the suspended solids, organic, and BaP data obtained in the RTI laboratory for the Ashtabula plant wastewater treatment pond system. All calculations in Tables 11 and 12 for BaP are based on data generated in RTI's laboratory by TLC analysis. This approach was used because the analysis method is consistent with other BaP determinations used in this project and because we are sure of sample handling, particularly recovery and extraction of the suspended solids. The reader should be aware, however, that RTI's analysis results differ from those determined by Stewart Laboratories, Inc. as pointed out below and that use of their data would lead to different results for BaP in the untreated wastewater and BaP content of the solids removed to the landfill. The suspended solids concentration in the composite pond inlet water sample was slightly over 4000 mg/L. Total solids discharged to the pond in a 24 hour period was calculated to be about 28,850 Kg. This number was calculated using outlet flow rate from pond 4D. The concentration of total organic matter in the influent was about 210 mg/L (1490 Kg/day). Of this, 17.5 mg/L was dissolved in the water and 193 mg/L was adsorbed on the suspended solids. The organic content of the solids was, therefore, 4.7 percent.

A total of 396 μg/L of BaP (2.8 Kg/day) was found in the portion of the sample analyzed at RTI (note that this differs from the 92 μg/L obtained by Stewart Laboratories, Inc. as given in Table 13 on what should have been an identical sample). All of the BaP was adsorbed on the suspended solids. BaP, therefore, constituted 0.19 percent of the total organic matter, 0.2 percent of the organic adsorbed on the solids, and 0.01 percent of the solids.

The water discharged from the treatment system contained no detectable BaP or suspended solids, and only 1 mg/L organic matter. The combination of solids settling (and removal) followed by chlorination resulted, therefore, in a dramatic improvement in water quality. Removal of suspended solids results in a 92 percent decrease in total organics and a 100 percent reduction in BaP.

Given in Table 12 are similar data from the Marietta wastewater treatment system. The influent suspended solids concentration was slightly more than 3000 mg/L. Total solids discharged into the pond per day were

TABLE 11. TSS, ORGANIC, AND BaP IN ASHTABULA PLANT WASTEWATER

| Component | Concentration in Sample | Entering Pond[a] per 24 hours, Kg |
|---|---|---|
| A. Wastewater Pond Inlet | | |
| Suspended Solids | 4,070 mg/L | 28,850 |
| Organics | | |
| Dissolved in Water | 17.5 mg/L | 124 |
| Adsorbed on Solids | 193.2 mg/L | 1,370 |
| Total | 210.7 mg/L | 1,490 |
| BaP | | |
| Dissolved in Water | ND[b] μg/L | 0 |
| Adsorbed on Solids | 396 μg/L | 2.8 |
| Total | 396 μg/L | 2.8 |
| | | Discharged from Pond[a] per 24 hours |
| B. Wastewater Pond Outlet | | |
| Suspended Solids | ND mg/L | ND |
| Organics, Total (all dissolved in water) | 1.0 mg/L | 7.1 |
| BaP, Total | ND μg/L | ND |

---

[a] Based on pond outlet flow rate of 4.29 $m^3$/min (1300 gpm).

[b] Below detection limts of: TSS, 0.05 mg/L; BaP, 0.25 μg/L.

TABLE 12. TSS, ORGANIC, AND BaP IN MARIETTA PLANT WASTEWATER

| Component | Concentration in Sample | Entering Pond[a] per 24 hours, Kg |
|---|---|---|
| A. Wastewater Pond Inlet | | |
| Suspended Solids | 3,023 mg/L | 44,400 |
| Organics | | |
| Dissolved in Water | 0.5 mg/L | 7.3 |
| Adsorbed on Solids | 2.4 mg/L | 35 |
| Total | 2.9 mg/L | 42 |
| BaP | | |
| Dissolved in Water | ND[b] μg/L | ND |
| Adsorbed on Solids | 2.4 μg/L | 0.035 |
| Total | 2.4 μg/L | 0.035 |
| | | Discharged from Pond[a] per 24 hours, Kg |
| B. Wastewater Pond Outlet | | |
| Suspended Solids | ND mg/L | ND |
| Organics, Total | ND mg/L | ND |
| BaP, Total | ND μg/L | ND |

[a] Based on pond outlet flow rate of 10.2 $m^3$/min (2700 gpm).

[b] Below detection limits of: TSS, 0.05 mg/L; organics, 0.05 mg/L; BaP, 0.25 μg/L.

calculated to be about 44,400 Kg based on outlet flow rate from the pond system of 10.2 $m^3$/min. Total organic concentration in the pond influent water was 2.9 mg/L (42 Kg/day). Of this, 0.5 mg/L was dissolved in the water and 2.5 mg/L adsorbed on the suspended solids. The organic content of the solids was, therefore, 0.08 percent.

A total of 2.4 μg/L of BaP g/L of BaP (0.035 Kg/day) was found in the portion of the sample analyzed at RTI (this also differs from the 13 μg/L determined by Stewart Laboratories, Inc. as given in Table 13 on a separate portion of the sample). All of the BaP was adsorbed on the suspended solids. BaP, therefore, constituted 0.08 percent of the organic matter, 0.1 percent of the organic matter adsorbed on the solids, and 8 x $10^{-5}$ percent of the solids.

Water discharged from the ponds contained no detectable solids, organic, or BaP. Detection limits were, respectively, 0.05 mg/L, 0.05 mg/L, 0.25 μg/L. These limits also apply to the samples from Ashtabula. Thus, the ponding system, which allows solids settling and holding time, resulted in a substantial improvement in water quality. Removal of suspended solids results in an 83 percent reduction in organics and a 100 percent reduction in BaP.

The samples were also analyzed for EPA designated priority pollutants. Given in Table 13 are the compounds detected in these samples. A complete list of all compounds analyzed for can be found in Section 9.

It can be seen that the samples from Ashtabula contain a greater number of priority pollutants, and at generally higher concentrations, than the Marietta samples. The Ashtabula pond inlet sample contains a wide variety of compounds including volatiles (e.g., benzene), polynuclear aromatic hydrocarbons (e.g., naphthalene), phenols, pesticides (e.g., 4,4' DDT), PCBs, and metals. Some of these compounds are known or suspected mutagens and carcinogens (e.g., benzo(a)pyrene). The sample also contains a number of pesticides. The plant reports they do not use these materials. It is possible these compounds were not added by the plant but were in the intake water from Lake Erie. However, we cannot prove this since a sample of the plant intake water was not obtained.

TABLE 13. PRIORITY POLLUTANTS DETECTED IN WASTEWATER TREATMENT SYSTEMS
(concentrations in $\mu g/L$)

| Compound | Ashtabula | | Marietta | |
|---|---|---|---|---|
| | Pond Inlet | Pond Outlet† | Pond Inlet | Pond Outlet† |
| Benzene | 460 | 21 | - | - |
| Chlorobenzene | - | - | - | <10 |
| Bromodichloromethane | - | <10 | - | - |
| Chloroform | <10 | 70 | - | - |
| Ethylbenzene | 10 | <10 | - | - |
| Methylene Chloride+ | 27 | 18 | <10 | <10 |
| Toluene | 250 | 11 | - | - |
| Naphthalene | 1200 | <10 | - | - |
| 2-Chloronaphthalene | - | <10 | - | - |
| Acenaphthylene | 990 | <10 | <10 | - |
| Acenaphthene | 25 | <10 | <10 | - |
| Fluorene | 280 | <10 | - | - |
| Anthracene | 250 | <10 | <10 | - |
| Fluoranthene | 200 | <10 | 71 | 15 |
| Pyrene | 150 | <10 | 54 | <10 |
| Chrysene | 71 | - | 16 | - |
| bis(2-ethylhexyl)phthalate | - | <10 | - | - |
| Benzo(a)anthracene | 71 | - | 10 | - |
| Benzo(b)fluoranthene | 38 | - | <10 | - |
| Benzo(k)fluoranthene | 1000 | - | - | - |
| Benzo(a)pyrene | 92 | - | 13 | - |
| Indeno(1,2,3-cd)pyrene | <10 | - | - | - |
| Benzo(g,h,i)perylene | 15 | - | - | - |
| 2-chlorophenol | - | 20 | - | - |
| Phenol | 2200 | - | - | - |
| 2,4-dichlorophenol | - | 35 | - | - |
| p-chloro-m-cresol | - | 10 | - | - |
| 2,4,6-Trichlorophenol | - | 35 | - | - |
| 2,4-Dimethylphenol | 450 | <10 | - | - |
| Aldrin | - | < 1 | - | - |
| 4,4'-DDT | 10 | <10 | - | - |
| 4,4'-DDD(p,p'-TDE) | - | < 1 | - | - |
| Endosulfan Sulfate | < 4* | - | - | - |
| Endrin Aldehyde | < 1 | <10 | - | - |
| Heptachlor | <10 | <10 | - | - |
| Heptachlor Epoxide | - | < 1 | - | - |
| α-BHC | <1 | <10 | - | - |
| β-BHC | <10 | <10 | - | - |

continued

- Blank spaces indicate compound not detected.

* Higher detection limit due to interference.

< Symbol indicates compound identified but at less than stated concentration.

+ Methylene chloride was used to clean the sample bottles.

† Pond outlet flow rates at the time of testing were Ashtabula, 4.92 $m^3$/min (1300 gpm), Marietta, 10.2 $m^3$/min (2700 gpm).

TABLE 13 (continued).

| Compound | Ashtabula | | Marietta | |
|---|---|---|---|---|
| | Pond Inlet | Pond Outlet† | Pond Inlet | Pond Outlet† |
| γ-BHC (Lindane) | <1 | <10 | - | - |
| δ-BHC | <10* | <10 | - | - |
| Toxaphene | < 5* | <10 | - | - |
| Chlorodane | - | <10 | - | - |
| PCB(Aroclor)-1221 | <20* | <20 | - | - |
| -1232 | - | < 2 | - | - |
| -1242 | - | < 1 | - | - |
| -1248 | - | < 1 | - | - |
| -1254 | - | < 2 | - | - |
| -1260 | - | < 2 | - | - |
| -1016 | - | < 1 | - | - |
| Antimony | 520 | 29 | 164 | 13 |
| Arsenic | 1,020 | 10 | 1,930 | 3 |
| Beryllium | < 1 | < 1 | <10* | <10* |
| Cadmium | 31 | < 1 | 310 | < 1 |
| Chromium | 190 | <10 | 52,000 | 90 |
| Copper | 560 | 6 | 810 | 20 |
| Lead | 20,200 | 20 | 1,020 | <10 |
| Mercury | < 1 | < 1 | 6 | < 1 |
| Nickel | 200 | <10 | 2,600 | 100 |
| Thallium | <10 | <10 | 100* | <100* |
| Selenium | 69 | < 1 | 26 | 11 |
| Silver | 28 | < 2 | 58 | 220 |
| Zinc | 10,100 | 25 | 13,000 | 10 |

- Blank spaces indicate compound not detected.

* Higher detection limit due to interference.

< Symbol indicates compound identified but at less than stated concentration.

+ Methylene chloride was used to clean the sample bottles.

† Pond outlet flow rates at the time of testing were Ashtabula, 4.92 $m^3$/min (1300 gpm), Marietta, 10.2 $m^3$/min (2700 gpm).

The treated effluent from the Ashtabula plant contained significantly less of most compounds found in the inlet. In particular note that the effluent contains none of the carcinogenic polynuclear aromatic hydrocarbons. Also note that the metals concentrations are also very low.

There is, however, an increase in two categories--chlorophenols and PCBs. Since the effluent is chlorinated, it is not surprising to find an increase in the chlorophenols. The concentration of these compounds in the treated effluent is quite low. PCB (Aroclor)-1221 was detected in the untreated wastewater at 20 μg/L. It is possible that this compound was also contained in the plant intake. The effluent, however, contained six additional PCBs with chlorine content greater than PCB-1221, each less than 1 to 2 μg/L. This implies that the additional PCBs were formed in the wastewater chlorination step by addition of chlorine to the PCB in the pond inlet water. Although these concentrations seem quite low, PCBs are a particularly toxic class of compounds. EPA's Toxic Pollutant Effluent Standard for this class of compounds is "no discharge permitted based on ambient criterion of 0.001 μg/L.[7]" It appears, therefore, that this discharge should be of concern to EPA's policy and regulatory authorities.

It should be noted, however, that the PCB analysis was done by standard EPA pesticide analyses by gas chromatography with $Ni^{63}$ electron capture and Tracor Model 700 Hall electrolytic conductivity detectors. This analysis is prone to interferences and does not definitely prove PCBs are present.

In the contractor's opinion, these results may require a basic policy decision by EPA. Some possibilities are:

1. Should EPA recommend an alternate treatment technology for cyanide and phenol destruction when the untreated water contains precursors of PCBs (i.e., biphenyl, and PCBs which are not fully chlorinated)? or,
2. Should EPA recognize that these type compounds will be formed if the recommended treatment procedures are followed and allow a net discharge based on fully chlorinating the precursor? or,
3. Should EPA require that treatment plants meet the no discharge restriction regardless of the source of the precursor.

The Marietta pond inlet samples contained fairly low concentrations of several organic compounds, including benzo(a)pyrene. The inlet sample also contains detectable quantities of all metals on the EPA priority pollutant list. The highest concentration detected was chromium at 52 mg/L. The electrolytic chromium production shop is the likely source of this material.

The Marietta plant effluent contains very little organic material and no organic carcinogens on the priority pollutant list. The metal concentrations in the effluent were all, with the exception of silver, significantly lower than found in the pond influent. Effluent chromium concentration was only 0.09 mg/L.

The difference observed in the organic content of the two pond influents probably is due to the differing extent of combustion under the furnace covers and to the pretreatment occurring for the Marietta wastewater. Furnaces at Ashtabula are operated with little combustion of the gas under the furnace covers since the high concentration carbon monoxide gas so generated is used as fuel in the lime kiln. There is substantial undercover combustion of the gas in the Marietta furnaces. It is to be expected that the difference in combustion would result in differences in the amount and type of organics trapped in the respective scrubbing systems. In addition to this difference, the furnace scrubber water at Marietta is mixed with effluent from the oxygenation of electrolytic shop wastewater. The oxygen residual contained in that water likely also reacts with organic contained in the scrubber water.

## 2.12 SOLID WASTE

In the course of testing, samples were taken of various materials that will eventually end up in a solid waste disposal area. This includes baghouse dusts, solids in scrubber discharge waters, and solids in the inlet to waste treatment ponds. It should be understood that the information collected does not constitute a complete assessment of solid waste generated and disposed of by the plants. Generally, the information is useful in assessing the impact operation of a particular type furnace producing specific products would have on the solid waste disposed of by a plant.

Some of the data here has been mentioned in the preceding parts of this section. These and additional data on the results of leaching tests done on several solids are presented here as an effort to make the data more easily comprehendable.

Given in Table 14 are the amounts of inorganic solids collected by the emission control systems and the amounts of organic matter and BaP adsorbed on those solids. Rates of generation of these materials are given in terms of MW-hr of furnace power to allow rapid extrapolation of the data to other similar furnaces. Percentages of organic and BaP in the total solids are also given.

Column three of the table gives the amount of inorganic solids collected by the capture equipment. These numbers are simply the difference in the amounts in the inlet to and exit from the control devices and can be calculated directly from the appropriate tables in Sections 6 through 10. Notice should be taken of calculation of two numbers. Inorganics captured by the secondary baghouses on the covered 50 percent FeSi furnace are calculated assuming a 98 percent capture efficiency (see Section 9.4). The covered FeMn furnace has no capture equipment for the secondary fume. We have estimated the solids that would be captured if 98 percent (for particulate) control were exercised. The organic and BaP numbers for this source are derived using the data obtained for gas samples assuming organic and BaP would be captured by the capture device in the same proportions as they were found to be adsorbed on the particulate matter.

It can easily be seen that the relative ordering (decreasing rate of inorganics solids) is Si metal, 50 percent FeSi (open and covered furnaces equivalent), open FeMn, and covered FeMn. The ratios are 13:3:2:1. It should be noted, however, that since the dust collected from the Si metal operations is a marketable product, some of this material does not end up in disposal areas.

The total organics associated with the solids are also presented in the table. Two sets of numbers are given. The first set represents actual analysis of dust removed from the baghouses. These are grab samples taken during the test period, not composites over the test period. The second set of numbers, in parentheses, are calculated as the difference in the inlet and outlet Method 5 organic results. As can be seen, in most cases there is a significant difference between the calculated result and the actual analysis

## TABLE 14. SOLID WASTE GENERATED BY FURNACES TESTED

| Furnace | Type | Inorganic Solids[a] per MW-hr Kg | Organics |  | BaP |  |  | Disposal Method |
|---|---|---|---|---|---|---|---|---|
|  |  |  | Total Adsorbed[b] on Solids Kg/MW-hr | % of Solids[c] | Total Adsorbed on Solids gms/MW-hr | % of Organic | % of Solids[c] |  |
| Si Metal | Open | 31.33 | 0.29<br>(0.72) | 0.90 | $5.2\times10^{-3}$ | $1.8\times10^{-3}$ | $1.6\times10^{-5}$ | Part used for ladle insulation, balance bagged and sold. |
| 50% FeSi | Open | 7.16 | 0.013<br>(0.22) | 0.19 | $1.6\times10^{-4}$ | $1.2\times10^{-3}$ | $2.0\times10^{-6}$ | Pelletized and disposed of off-site. |
| 50% FeSi | Covered |  |  |  |  |  |  | Slurried, solids removed in pond and placed in landfill on-site. |
| Secondary |  | 2.61 | 0.03<br>(0.07) | 1.1 | $2.1\times10^{-2}$ | $7.4\times10^{-2}$ | $8\times10^{-4}$ |  |
| Primary |  | 4.43 | 0.93 | 17.4 | 4.02 | 0.43 | $9\times10^{-2}$ |  |
| Total |  | 7.04 | 0.96 | 12 | 4.04 | 0.42 | $5\times10^{-2}$ |  |
| HC FeMn | Open | 4.69 | 0.007<br>(1.14) | 0.15 | $3.9\times10^{-3}$ | $5.7\times10^{-2}$ | $7\times10^{-5}$ | Disposed of off-site. |
| HC FeMn | Covered |  |  |  |  |  |  | Solids in scrubber settled in pond-dredged out and landfilled on-site. |
| Secondary |  | 0.76[d] | 0.003[d] | 0.4[d] | $1.5\times10^{-4}$[d] | $5\times10^{-3}$[d] | $2\times10^{-5}$[d] |  |
| Primary |  | 1.59 | 0.096 | 6.0 | $2.2\times10^{-2}$ | $2.3\times10^{-2}$ | $1.3\times10^{-3}$ |  |
| Total |  | 2.35 | 0.099 | 4.2 | $2.2\times10^{-2}$ | $2.2\times10^{-2}$ | $9.0\times10^{-4}$ |  |

[a] Excludes organics which should be added in to get total solid waste.

[b] Numbers in parentheses obtained by difference in organic found in inlet and outlet gas samples.

[c] Including organics.

[d] If secondary emissions were controlled 98% for particulates, 2.9% of organics, 98% of BaP.

of the dust. This, of course, raises some interesting questions. Which, if either, result is correct? If both are correct, what happened to the extra organic? In our opinion both sets of analytical results are valid. If so, then the discrepancy probably results from either or a combination of:

1. The baghouse dust sample was only a grab. The Method 5 data indicate considerable variability in inlet organic loadings.
2. The baghouse dust sample does not include material removed in the knockout chamber preceding the baghouse. If this material were heavily laden with organic it would explain the results.
3. The organic going to the baghouse is adsorbed on fine dust trapped in the fabric media, on the fabric itself, and on the interior surfaces of the baghouse, and subsequently reentrained in the exhaust gas. During its residence in the baghouse, some of the organic material may be destroyed by the oxidizing atmosphere in the baghouse.

We suspect items 1 and 3 to be the major contributors to the apparent discrepancy.

For comparison purposes, only the analysis of the actual baghouse dust is discussed. In terms of Kg of organic on the baghouse collected dust per MW-hr of furnace power, the furnace ranking in decreasing order is: Si metal, open FeSi, covered FeSi (secondary fume only), open FeMn, and covered FeMn (based on calculation assuming a baghouse were installed to capture secondary fume). However, when the furnaces are compared on the basis of organic adsorbed on all solids generated by the furnaces (i.e., including scrubber sludge from primary control system) the ranking is: covered FeSi, Si metal, covered FeMn, open FeSi, and open FeMn.

In addition to the total amount of organic contained on the solids potentially disposed, the percentage of organic in the total solids was also calculated. This provides some very interesting data. Note that the solids filtered from the scrubber discharge water of the covered FeSi furnace were about 17 percent organic and similar solids from the covered FeMn furnace were 6 percent organic. Substantially more undercover combustion of furnace gas was occurring in the FeMn furnace relative to the FeSi furnace. Despite organic contents of 1.1 and 0.4 percent on solids in the secondary fume from these respective furnaces, the overall average organic content of solids that could be disposed of was 12 and 4 percent for the FeSi and FeMn furnace, respectively. These numbers are for the furnaces only and do not consider any effect of intermingling with other process streams and assume the capture of secondary fume from the FeMn furnace stated in the table.

These percentages should be compared to the organic content of the baghouse dust from the open furnaces. The Si metal furnace had the highest solids organic content of these furnaces at 0.9 percent. Both the FeSi and FeMn furnaces contained less than 0.2 percent organic in the dust collected by the baghouse. Thus, in terms of the actual organic composition of solids for disposal, rather than mass per MW-hr of furnace power, it is obvious that the solid waste from open furnaces has a significantly lower organic content than does the solid waste from covered furnaces.

Table 14 also contains information on the BaP content of the solid waste. When compared on the basis of total BaP on the solids per MW-hr of furnace power, the relative ranking in order of decreasing BaP is: covered FeSi, covered FeMn, Si metal, open FeMn, and open FeSi. At 4 grams/MW-hr, the covered FeSi furnace solids have about 200 times as much BaP as do the covered FeMn furnace solids and about $2 \times 10^4$ as much as solids from the open FeSi furnace. Obviously, the lack of combustion occurring in the tightly covered FeSi furnace has a major effect on BaP accumulation in the solids. Note also that, for both covered furnaces, almost all of the BaP was contained on scrubber solids, i.e., particulate withdrawn from beneath the furnace cover. Over 99 percent of the BaP in the scrubber discharge water was adsorbed on the suspended solids.

The table also contains data on the percentage BaP in the organic matter associated with the solids. In most cases the BaP is below 0.1 percent of the organic matter. BaP is about 0.4 percent of the organic on solids from the covered FeSi furnace.

Also calculated is the percentage of BaP in the total solids. The BaP contents of the solids from the open Si metal and FeMn furnaces were $1.6 \times 10^{-5}$ and $7 \times 10^{-5}$ percent, respectively. For solids in the scrubber discharge water from the covered FeMn furnace, the BaP content was $1.3 \times 10^{-3}$ percent. Solids in the scrubber water discharged by the covered FeSi furnace contained $9 \times 10^{-2}$ percent BaP.

As discussed in Section 2.11, samples were also taken of wastes discharged to the pond systems at the two plants at which the covered furnaces were tested. In both cases, the slurry discharged to these ponds includes most process solid wastes generated by the plants, however, it does not include slag, sanitary wastes, etc. Since process data were not taken for all operations that might discharge solid waste into this system, it should be understood that the data for solids in the plant wastewater treatment may not be typical of plant operations.

At the Ashtabula plant (covered 50 percent FeSi), the solids settle out of the slurry in initial ponds before the clarified water is chlorinated. The settled solids are dredged out and placed in landfill. At the Marietta plant, the scenario is much the same, except that the water is not chlorinated. Therefore, it seems entirely logical to assume that solids removed from the slurry entering the pond is essentially the same as the solids dredged out and landfilled.

Making this assumption, then, the solid waste removed from the ponds and placed in on-site landfills would be as given in Table 15.

TABLE 15. SOLID WASTE FROM WASTEWATER TREATMENT PONDS

| Plant | Total Solids per 24 hr, Kg | Total Organics/24 hr Kg | Total Organics/24 hr % of Solids | BaP/24 hours Kg | BaP/24 hours % of Organics | BaP/24 hours % of Total Solids |
|---|---|---|---|---|---|---|
| Ashtabula | 28,850 | 1,370 | 4.7 | 2.8 | 0.2 | $1 \times 10^{-2}$ |
| Marietta | 44,400 | 35 | $8 \times 10^{-2}$ | 0.035 | 0.1 | $8 \times 10^{-5}$ |

Solids collected by the baghouses on the three open furnaces and solids filtered from the influent to the wastewater ponds at the two plants where the covered furnace tests were performed were further analyzed by atomic absorption spectroscopy for nine metals on EPA's Priority Pollutant list. The solids were then subjected to the leaching test following procedures in 40 CFR Part 261, May 19, 1980. The results are given in Table 16.

TABLE 16. LEACHING TEST RESULTS

| Solid Source | Sb | As[1] (5.0)[2] | Be | Cd (1.0)[2] | Cr (5.0)[2] |
|---|---|---|---|---|---|
| Si Metal Furnace, Baghouse Dust | | | | | |
| Original Solids, μg/g | $<4.6\times10^{-2}$ | 16.9 | $3.5\times10^{-2}$ | 0.219 | 64.0 |
| Leachate, mg/L | $<1.4\times10^{-2}$ | 1.29 | $<3\times10^{-5}$ | $3.2\times10^{-4}$ | $4.7\times10^{-2}$ |
| Amount Leached, μg/g | 0.281 | 25.8 | $<6\times10^{-4}$ | $6.4\times10^{-3}$ | 0.941 |
| % of Element Leached | -- | -- | 1.7 | 2.9 | 1.5 |
| Open H.C. FeMn Furnace, Baghouse Dust | | | | | |
| Original Solids, μg/g | 2.58 | 217 | 1.40 | 21.4 | 146 |
| Leachate, mg/L | $5\times10^{-2}$ | 0.411 | $6.1\times10^{-3}$ | $1.1\times10^{-3}$ | 0.309 |
| Amount Leached, μg/g | 0.99 | 8.22 | $3.3\times10^{-2}$ | $2.3\times10^{-2}$ | 6.17 |
| % of Element Leached | 38 | 3.8 | 2.3 | 0.1 | 4.2 |
| Open 50% FeSi Furnace, Baghouse Dust | | | | | |
| Original Solids, μg/g | 4.32 | 145 | 0.318 | 27.4 | 239 |
| Leachate, mg/L | $3.7\times10^{-2}$ | $<5\times10^{-2}$ | $5\times10^{-4}$ | 0.443 | $2.8\times10^{-2}$ |
| Amount Leached, μg/g | 0.734 | <1 | $9.9\times10^{-3}$ | 8.86 | 0.555 |
| % of Element Leached | 17 | 0.7 | 3.1 | 32.3 | 0.23 |
| Marietta Plant, WWT Pond Inlet Solids | | | | | |
| Original Solids, μg/g | 3.0 | 572 | 5.07 | 73.5 | 20,700 |
| Leachate, mg/L | $1.29\times10^{-2}$ | 0.112 | $2.1\times10^{-4}$ | 0.204 | 0.193 |
| Amount Leached, μg/g | 0.258 | 2.24 | $4.2\times10^{-3}$ | 4.08 | 3.86 |
| % of Element Leached | 8.6 | 0.4 | $8\times10^{-2}$ | 5.6 | $2\times10^{-2}$ |
| Ashtabula Plant, WWT Pond Inlet Solids | | | | | |
| Original Solids, μg/g | 16.6 | 289 | 0.564 | 7.65 | 148 |
| Leachate, mg/L | $3.8\times10^{-2}$ | 0.289 | $<3\times10^{-5}$ | $<1\times10^{-4}$ | 0.630 |
| Amount Leached, μg/g | 0.752 | 5.77 | $<6\times10^{-4}$ | $<2\times10^{-3}$ | 12.6 |
| % of Element Leached | 4.5 | 2.0 | 0.1 | $3\times10^{-2}$ | 8.5 |

continued

[1] Possible analytical interference.

[2] Maximum permissible leachate concentration, mg/L as per 40 CFR Part 261.24, May 19, 1980.

TABLE 16 (continued)

| Solid Source | Pb (5.0)[2] | Hg (0.2)[2] | Se (1.0)[2] | Tl |
|---|---|---|---|---|
| Si Metal Furnace, Baghouse Dust | | | | |
| Original Solids, μg/g | 14.3 | <0.62 | 2.78 | 0.122 |
| Leachate, mg/L | $<1 \times 10^{-3}$ | $<1.2\times10^{-2}$ | $5.9\times10^{-2}$ | $2.2\times10^{-3}$ |
| Amount Leached, μg/g | $<2 \times 10^{-2}$ | <0.25 | 1.17 | $4.5\times10^{-2}$ |
| % of Element Leached | 0.14 | -- | 42 | 37 |
| Open H.C. FeMn Furnace, Baghouse Dust | | | | |
| Original Solids, μg/g | 2180 | <0.62 | 11.0 | 15.4 |
| Leachate, mg/L | $2.8\times10^{-3}$ | $<1.2\times10^{-2}$ | 0.463 | $6.9\times10^{-3}$ |
| Amount Leached, μg/g | $5.5\times10^{-2}$ | <0.25 | 9.28 | 0.139 |
| % of Element Leached | $3 \times 10^{-3}$ | -- | 84 | 0.9 |
| Open 50% FeSi Furnace, Baghouse Dust | | | | |
| Original Solids, μg/g | 2680 | <0.62 | 75.7 | 2.96 |
| Leachate, mg/L | $<1 \times 10^{-3}$ | $<1.2\times10^{-2}$ | 0.28 | $2.3\times10^{-3}$ |
| Amount Leached, μg/g | $<2 \times 10^{-2}$ | <0.25 | 5.61 | $4.6\times10^{-2}$ |
| % of Element Leached | $\sim 7 \times 10^{-4}$ | -- | 7.4 | 1.6 |
| Marietta Plant, WWT Pond Inlet Solids | | | | |
| Original Solids, μg/g | 436 | <0.62 | <2.3 | 13.3 |
| Leachate, mg/L | $<1 \times 10^{-3}$ | $<1.2\times10^{-2}$ | $<6 \times 10^{-2}$ | $5.7\times10^{-3}$ |
| Amount Leached, μg/g | $<2 \times 10^{-2}$ | <0.25 | <1.25 | 1.15 |
| % of Element Leached | $\sim 5 \times 10^{-3}$ | -- | 54? | 8.6 |
| Ashtabula Plant, WWT Pond Inlet Solids | | | | |
| Original Solids, μg/g | 4720 | <0.62 | 23.0 | 2.20 |
| Leachate, mg/L | $<1 \times 10^{-3}$ | $<1.2\times10^{-2}$ | $8.1\times10^{-2}$ | $5.1\times10^{-4}$ |
| Amount Leached, μg/g | $<2 \times 10^{-2}$ | <0.25 | 1.63 | $1.01\times10^{-2}$ |
| % of Element Leached | $\sim 4 \times 10^{-4}$ | -- | 7.1 | 0.46 |

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[1] Possible analytical interference.

[2] Maximum permissible leachate concentration, mg/L as per 40 CFR Part 261.24, May 19, 1980.

The concentrations of some of the elements in the leachate can be compared to maximum permissible levels given in 40 CFR Part 261.24 May 19, 1980. Exceeding these levels would result in classification of the solid as a hazardous waste. The permissible levels are (in mg/L): As (5.0), Cd (1.0), Cr (5.0), Pb (5.0), Hg (0.2), Se (1.0). None of the elements in any of the solids exceed the permissible levels. Thus, on this basis only, none of the solids would be classified as hazardous wastes.

We note in comparing data on the elements in different solids that there appears to be no uniformity in the percentage or amount of the element that is extracted. We also note that, in general, there is no uniformity in the concentration of the elements in the leachate from the solids. The leachates from all solids did, however, contain about the same concentration for each of the three elements antimony, lead, and thallium.

## 2.13 GROUNDWATER

Samples were obtained at the Ashtabula plant of the groundwater immediately up-gradient and immediately down-gradient of the landfill--wastewater treatment pond area. (For exact locations see Figure 12, Section 9).

RTI analyzed these samples for organics and BaP. Both components were below the detection limits. Since only 1 liter of each sample could be obtained, the detection limits are somewhat higher than for other samples obtained. The detection limits are for organics, 0.1 mg/L; for BaP 0.5 μg/L.

Included in Table 17 are the concentrations of metals in the groundwaters. The results were supplied to RTI by the company. The company routinely reports these analyses to the Ohio Environmental Protection Agency.

As can be seen from the table, only four elements (Al, Mg, Mn, and Ni) had a higher concentration down-gradient of the waste treatment area than existed in the up-gradient water. Furthermore, the data show that several metals actually decreased in concentration.

Based on these data, it does not appear that there is any significant leaching of materials in the landfill or percolation of water from the wastewater treatment ponds into the underlying aquifer.

TABLE 17. ANALYSIS OF GROUNDWATER AT ASHTABULA[a]

| Component | Up-Gradient mg/L | Down-gradient mg/L |
|---|---|---|
| Al | 0.31 | 1.51 |
| Ba | 0.22 | <0.01 |
| Cd | 0.005 | <0.002 |
| Cr | <0.001 | <0.001 |
| Cu | 0.025 | 0.020 |
| Fe | 22.0 | 0.80 |
| Mg | 65.5 | 120.9 |
| Mn | 1.21 | 1.88 |
| Ni | 0.010 | 0.025 |
| Pb | <0.01 | <0.01 |
| Zn | 0.074 | 0.060 |
| Organics[b] | <0.1 | <0.1 |
| BaP[c] | <0.0005 | <0.0005 |

[a] Metals analysis supplied by company and reported to Ohio Environmental Protection Agency. Samples taken immediately up- and down-gradient of the landfill--wastewater treatment area.

[b] Detection limit - 0.1 mg/L.

[c] Detection limit - 0.0005 mg/L.

## 2.14 GC-MS ANALYSIS OF BAGHOUSE EMISSION SAMPLES

The samples collected during baghouse outlet testing at the silicon metal furnace and the covered ferrosilicon furnace (secondary fume only, during production of 65 percent FeSi) were analyzed by GC-MS for polynuclear aromatic hydrocarbons. All samples obtained during each baghouse test were composited for the analyses. These two sources were selected for this analysis because mass spectral analysis was not available from previous studies. Given in Table 18 are the results obtained. Several compounds identified were present at such low concentrations in the sample analyzed that the quantitation is suspect. In addition, BaP and BeP were not resolved. Thus, these data cannot be compared to other data on BaP from these sources. Although the GC-MS did not report BaP for the FeSi furnace, the other data presented indicate it is probably present at a concentration below the GC-MS detection limit for the particular sample analyzed.

Of the compounds positively identified, only chrysene and benzo(a)-anthracene are known carcinogens. BaP is, of course, a powerful carcinogen but BeP is noncarcinogenic. The concentration and amount emitted of the two compounds is quite low.

To provide some measure of the environmental impact of the polynuclear aromatic hydrocarbon (PAH) emissions, they can be compared to the threshold limit value (TLV) of 0.2 mg/m$^3$ for particulate PAH (PPAH) in the work place.[8] Atmospheric dilutions of only 8 (Si metal) and 3 (FeSi) would be required to reduce the concentration to the PPAH TLV.

Samples from both furnaces contained biphenyl. Since this compound has a boiling point over 250°C (480°F), it is quite likely adsorbed on the baghouse dust. Since, at the Ashtabula plant (covered FeSi furnace), this dust is slurried and discharged to the wastewater treatment system, it is possible that the polychlorinated biphenyls detected in the plant effluent were formed through chlorination of this compound.

TABLE 18. GC-MS ANALYSIS OF BAGHOUSE EMISSION SAMPLES, SILICON METAL AND COVERED FeSi FURNACE

| | Silicon Metal Furnace[a] | | Covered FeSi Furnace, Secondary Fume[b] | |
|---|---|---|---|---|
| | Concentration in Gas, µg/m$^3$ | Emitted per hour grams | Concentration in Gas, µg/m$^3$ | Emitted per hour grams |
| Naphthalene | 957 | 629 | 433 | 279 |
| Biphenyl | 141 | 92.4 | 37 | 24 |
| Fluorene | 14 | 9.3 | 9[c] | 6[c] |
| Anthracene | 172 | 113 | 57 | 37 |
| Methylanthracenes[c] | 50 | 33 | 2 | 1 |
| Phenylnaphthalene | 41 | 27 | 20 | 10 |
| Fluoranthene | 66 | 43 | 20[c] | 10[c] |
| Pyrene | 37 | 24 | 9[c] | 6[c] |
| Chrysene | 10 | 7 | 2[c] | 1[c] |
| Benz(a)anthracene[c] | 4 | 2 | -- | |
| Benzo(a and e)pyrene[c] | 51 | 33 | -- | |
| Total: | 1,565 | 1,028 | 589 | 374 |

[a] All samples from baghouse outlet runs 1, 3, and 4 combined for single analysis.

[b] All samples from baghouse outlet runs combined for single analysis.

[c] Quantitation suspect due to low level of compound in sample analyzed.

## 3.0 CONCLUSIONS

In this project, environmental data were collected for five furnaces. Each test period lasted less than five days. It should be recognized, therefore, that the data are based on a limited test program and represents the performance of individual systems under specific operating conditions. Frequently throughout this report, especially when comparisons are made, the data are used to represent typical performance of similar furnaces producing similar products. These statements are more properly indicators of trends and undue significance should not be attached to numerical ratios.

An effort has been made to use sufficiently specific language that mistaking data taken before control devices for actual emissions to the environment is unlikely. The term "generated" is used to refer to materials entering a collection or control device. The term "emitted" is used only to refer to material actually entering the atmosphere.

1. The total amount of particulate matter generated by the furnaces per megawatt-hr (MW-hr) of furnace power input increases for different alloys in the order ferrmomanganese (FeMn), ferrosilicon (FeSi), and Si metal in the approximate ratios of 1:2:9, respectively. Based on the limited test data, there appears to be little significant difference in the particulate generation rates of open and covered furnaces producing similar products.

2. Particulate emissions to the atmosphere from the Si metal furnace, and the covered furnaces producing FeMn and FeSi exceeded NSPS do not apply to these furnaces and are used here only as a reference mark for discussion. The data indicate that similar new furnaces could achieve NSPS compliance with similar well designed and operated control equipment.

3. The total amount of organic matter generated per MW-hr of furnace power increases in the following order of furnace and product types: covered FeMn with substantial undercover combustion, open FeSi, covered FeSi with little under combustion, open FeMn, and open Si. The data suggest that organic generation rates are

significantly lower in covered furnaces with substantial undercover combustion than covered furnaces in which this does not occur and may be as low or lower than organic generation rates of open furnaces producing equivalent products.

4. The data indicate that open furnaces emit as much or more organic matter to the atmosphere as do covered furnaces producing equivalent products. A major reason for this is that the scrubbers used on covered furnaces remove a greater percentage of the organic matter from gas from covered furnaces than baghouse remove from gas from open furnaces. No testing was done to determine if scrubbers would remove a greater percentage of organic matter from gas from open furnaces than is achievable with baghouses.

5. The average total amount of BaP generated per MW-hr of furnace power increases in the following order of furnace type and product: open FeMn, none detected in any test; open FeSi, detected in two of five tests; covered FeMn (but with substantial undercover combustion), detected in all tests, and open Si, detected in four of six tests; and covered FeSi, detected in all tests. Since the data indicate that the tightly covered FeSi furnace generated 4 g/MW-hr, about 180 times as much BaP as did the next highest ranking furnace, we concluded that, in general, tightly covered furnaces would generate substantially more BaP than other furnace types producing equivalent products.

6. BaP was detected in the emissions to atmosphere from only three of the five furnaces tested: Si metal, detected in one of three tests; covered FeSi, detected in all tests; and covered FeMn, detected in two of five tests. Emission rates decrease in the order given. The mass of BaP emitted was less than 0.01 g/MW-hr and less than 0.25 g/hr for each furnace.

7. The average organic content of solid wastes from the pollution control systems of the covered FeSi and FeMn furnaces was 12 and 14 percent, respectively, significantly greater than found for solids from the open furnaces--0.9 percent from Si metal and less than 0.2 percent for FeSi and FeMn. In addition, BaP comprised about 0.4 percent of the organics found on solids from the covered FeSi furnace but less than 0.1 percent of the organic on solids from the other four furnaces. Concentrations found were 0.02, 0.18, 0.78, 9.0, and 480 μg BaP/g solid for open FeSi, Si metal, open FeMn, covered FeMn, and covered FeSi, respectively. These data suggest that solids from open furnaces are less likely to contain hazardous amounts of organics, including BaP, than are solids from covered furnaces.

8. Wastewater entering the water treatment system at the two plants tested that use covered furnaces contain a wide variety of EPA designated priority pollutants. More compounds and higher concentrations were found at the plant using the tightly covered

FeSi furnace. The treated effluent contained low concentrations of all detected priority pollutants, including metals. No carcinogenic polynuclear aromatic hydrocarbons were detected in the effluents. The data indicate that simply removing suspended solids from the untreated water would result in 80-90 percent reduction in discharged organics and 100 percent removal of BaP. These data indicate the wastewater treatment methods in use are effective in controlling the discharge of water-borne pollutants.

9. Monochlorinated biphenyl was detected at <20 μg/L in the untreated wastewater at the Ashtabula plant (covered FeSi furnace). This compound, as well as several pesticides also found, may have been in the plant intake water from Lake Erie. Several additional polychlorinated biphenyls (PCBs), each at less than 2 μg/L, were detected in the treated discharge. These data suggest the possibility that the plants' use of a state-of- the-art technology, chlorination, for phenol and cyanide destruction results in PCB formation in this water. The analytical technique used, however, leaves some question about the PCB identifications (see page 37).

10. The limited test data suggest that solid wastes removed from the wastewater treatment system and placed in on-site landfills would be about $1 \times 10^{-2}$ and $8 \times 10^{-5}$ percent BaP for the Ashtabula and Marietta plants, respectively. Analysis of one pair of up- and down-gradient groundwater samples around the landfill-wastewater pond system at the Ashtabula plant indicates that neither organic matter, including BaP, nor heavy metals leach or percolate into the underground aquifer. These limited data suggest that this method of disposal does not present a clear and present danger to underground aquifers.

11. No metals were leachable, following the EPA-OSW extraction procedure, from any of the solid wastes, including baghouse dusts, scrubber sludges, and wastewater treatment plant sludge, in sufficiently high concentrations to result in classifying the wastes as hazardous.

# 4.0 RECOMMENDATIONS

The test data presented in this report indicate that, in general, the ferroalloy industry does a good job in preventing discharge of generated pollutants into the environment.

However, despite efforts by at least one company, further development is needed to find a solution to the rapid failure of the bags in baghouses handling fume from Si metal production. These failures are not only expensive, in both time and money expended, but also result in periods of increased particulate emissions to the atmosphere. This product line is the largest, in terms of installed MW capacity (but not product tonnage), in the industry; baghouses are the common method of fume control.

The test data show that, in general, organic emissions to the atmosphere actually exceed the particulate emissions. The percentage capture of organics by baghouses seem to decrease with increasing operating temperature of the baghouse. The industry uses several methods, such as introduction of dilution air, heat exchangers, water sprays, etc., to reduce gas temperatures to protect baghouse components. Further reductions in gas temperatures would be expensive, possibly impractical for retrofit application, and may still not reduce organic significantly. Average benzo(a)pyrene emission to the atmosphere (BaP not detected in all tests) exceeded 0.13 $\mu g/m^3$ at three of the five furnaces tested: Si metal, and the covered FeSi and H.C. FeMn furnaces. The mass of BaP emitted was, however, less than one gram per hour for any of the three furnaces. All of the emissions occurred through the baghouse systems, i.e., secondary fume only for covered furnaces. Atmospheric modeling studies would be required to determine the significance of these emissions.

Solid wastes from the pollution control systems of all furnaces tested except the open FeSi furnace contained a concentration of BaP greater than

0.16 μg BaP/g solid. All test data, which include groundwater analysis at one plant and extraction in acidic solution, the OSW procedure for metals leaching test, indicate the BaP does not leach from the solids. Thus, we recommend that the waste not be categorized as hazardous on the basis of possible leaching of BaP into groundwater.

Analysis of the untreated and treated wastewater at the Ashtabula ferroalloy plant suggests the possibility that chlorination of the wastewater, the state-of-the-art technology for cyanide and phenol destruction, may have resulted in the further chlorination of a PCB compound tentatively identified in the untreated water. If this identification can be confirmed, we recommend that EPA review its recommendation of this technology for applications where PCBs or PCB precursors, biphenyl, for example, may be in the water to be chlorinated. This recommendation is not restricted to the ferroalloy industry.

We find the current wording of the NSPS standards for this industry to be confusing. "Ferrosilicon" is defined in the standards as an alloy meeting certain ASTM designation and containing 50 percent or more silicon. Also, "silvery iron" is defined as a ferrosilicon containing 30 percent or less silicon. There is no definition or reference to a ferrosilicon with silicon content between these two or to products not meeting all requirements of the ASTM designations. Particulate emission limits are then given for the two products (and others) of 0.45 Kg/MW-hr for "ferrosilicon" and 0.23 Kg/MW-hr for "silvery iron." The question obviously raised is which standard applies to "ferrosilicon" with silicon contents between 30 and 50 percent or which do not meet the ASTM designations. It appears that a problem could occur under the following scenario. Assume that a new furnace is built which is designed to produce products of nominal 50, 65, and 75 percent FeSi. The furnace emission control system would be compliance certified while 75 percent FeSi was being produced since this is the product with the highest fume generation rate. The assumption would be that emissions would be less than 0.45 Kg/MW-hr during production of any product generating less fume. Now suppose the furnace is used to produce a nominal 50 percent grade FeSi and makes a product containing 48 percent Si, which falls within the ASTM specifications for the product. As we interpret the NSPS, this product is not eligible for the 0.45 Kg/MW-hr emission rate since it contains less than 50 percent silicon. It is possible that the furnace emission reduction system would not be in compliance with the 0.23 Kg/MW-hr standard but this cannot be verified since no relevant compliance testing would have been done.

We recommend that EPA review this subject in detail during the next review of the NSPS for The Ferroalloy Industry.

Neither of the two "50 percent ferrosilicon" furnaces tested in this study were producing a product containing 50 percent or more silicon. Standard 50 percent ferrosilicon as defined by ASTM designation A100-69 grade E contains 47-51 percent silicon. Throughout this report we have adapted the convention that a ferrosilicon product not containing 50 percent or more silicon would be subject to the more restrictive emission limit.

# 5.0 SITE SELECTION AND TESTING RATIONALE

## 5.1 SITE SELECTION

Sites were selected for testing based on the primary considerations of:

1. The need to compare similar products produced in both open and covered furnaces.
2. Percentage of total industry capacity (installed MW capacity basis) the product represents.
3. Percentage of industry capacity (MW basis) devoted to open and covered furnaces.
4. Testability of sites (ductwork sufficiently segregated that individual furnace could be tested, etc.)
5. The source appeared to be well controlled.

Listed in Table 19 are some general industry usage statistics. These figures are based on a detailed itemization of furnaces provided to RTI by The Ferroalloy Association in May 1980.

Since silicon and ferrosilicon products represent the largest segment of the industry, the decision was made to focus efforts in this area. The testing program includes one open furnace producing silicon metal and using baghouse emission reduction equipment; one open furnace producing 50 percent ferrosilicon and using a baghouse; one covered furnace producing 50 percent ferrosilicon and using scrubbers to capture primary fumes (secondary fumes from the furnace cover are captured by a baghouse). The exact furnaces to be tested were selected based on knowledge acquired in the previous sampling program, recommendations contained in a draft report prepared for EPA/IERL by GCA Corporation, contacts with industry representatives, and on-site inspections. The furnaces selected producing silicon products were:

1. Silicon Metal - Interlake, Inc., Selma, Al, furnace No.2.

2. 50 percent ferrosilicon, open - Foote Mineral, Co., Graham, WV, furnace No.2.

3. 50 percent ferrosilicon, covered - Union Carbide Corp., Ashtabula, OH, furnace No.20.

TABLE 19. FURNACE STATISTICS (May 1980)

| Furnace Product | Approximate Capacity, MW | % of Capacity | % Using Open Furnace | % Using Baghouse | % Using Scrubber | % Using ESP |
|---|---|---|---|---|---|---|
| Si, metal | 355 | 23.5 | 100 | 100 | 0 | |
| 50%, FeSi | 222 | 14.7 | 79.7 | 68.5 | 31.5 | |
| 75%, FeSi | 125 | 8.3 | 100 | 100 | 0 | |
| FeSi, any grade | 241 | 16.0 | 100 | 92.5 | 7.5 | |
| SiMn | 146 | 9.7 | 81.5 | 52.7 | 47.3 | |
| FeMn | 106 | 7.0 | 53.8 | 39.6 | 60.4 | |
| FeMnSi | 18 | 1.2 | 100 | 100 | 0 | |
| FeCr | 159 | 10.5 | 84.9 | 19.5 | 30.2 | 50.3 |
| FeCrSi | 76 | 5.0 | 100 | 78.9 | 21.1 | |
| CrSi | 11 | 0.7 | 100 | 100 | 0 | |
| CaSi | 15 | 1.0 | 100 | 100 | 0 | |
| Silvery iron | 35 | 2.3 | 0 | 0 | 100 | |
| Totals: | 1,509 | 99.9 | 88.1 | 73.5 | 21.1 | 50.3 |

At the time the furnace testing decisions were being made, production of chrome based alloys was significantly below capacity. Furthermore, almost all of this production is in open furnaces which would limit our ability to compare the production in open and covered furnaces. This essentially restricted the choice to the FeMn or SiMn products. SiMn is produced in several open furnaces but only one covered furnace in the United States. This furnace was not operating when furnace selections were being made. Thus, the choice was restricted to FeMn. Based on prior knowledge, industry contacts and on-site visits, the following FeMn producing furnaces were selected for testing:

1. Covered FeMn furnace - Union Carbide Corp., Marietta, OH, furnace No.17 - scrubber emission control.
2. Open FeMn furnace - Roane, Ltd. (SAMANCOR), Rockwood, TN, furnace No.3 and 4. These furnaces were operating simultaneously and use common ductwork and baghouse for emission control.

## 5.2 TESTING RATIONALE

Testing will be discussed separately in terms of sample acquisition and sample analysis.

### 5.2.1 Sample Acquisition

The previous Level 1 sampling program[6] yielded fairly imprecise results (± a factor of 3). For this program, sampling was done where possible by EPA Methods 1-5 (see Sections 6 through 10 and the Appendix for details) for determining particulate loadings. A cartridge filled with XAD-2 resin was installed in the Method 5 sampling train to capture organics.

For all open-type furnaces, samples were taken in the duct leading from the furnace and before any pollution control equipment. Simultaneously, samples were taken in the baghouse exhaust. Exhaust samples were taken for longer periods of time than inlet samples, however, and occasionally overlapped two inlet tests or parts of two inlet tests. The exhaust samples were taken by inserting probes through the baghouse upper access doorways, above the bags just before the gas exits the roof monitor. Because of the low particulate concentration and low gas velocity, the baghouse exhaust samples were taken at much greater than isokinetic rates. However, since the particulate was expected to be of very small aerodynamic diameter, the isokinetic rate should have little, if any, effect on the total particulate concentration determined. Also, since the baghouses had 11 to 14 individual compartments, each outlet sample was composed of a single point sample in each of four compartments. Succeeding samples were taken in four different compartments so that all compartments were sampled before testing was completed. For each furnace, five or six inlet samples were taken and three to five outlet samples were taken.

Since covered furnaces use two separate emission control systems, a different approach was taken.

At the Ashtabula plant (covered 50 percent ferrosilicon) secondary emissions are treated in a baghouse. Also, since water sprays are used throughout the primary duct leading from beneath the furnace cover to the scrubber no meaningful particulate sample could be taken in this location. Therefore, particulate sampling was done simultaneously in the primary system ductwork after the scrubber and also in the secondary ductwork before the baghouse by EPA Method 5. At the same time, samples were taken, using an automatic sampler, of the scrubber discharge water and the flow rate measured. A scrubber feedwater sample was also collected during testing. The capture efficiency of the baghouse was determined by simultaneous Method 5 testing before and after the baghouse. These tests were not, however, simultaneous with the testing in the primary system. For the baghouse exhaust tests, only four of the 14 outlet compartments were sampled. The same four compartments were sampled for each test.

At the Marietta plant (covered ferromanganese) secondary emissions exhaust directly to atmosphere (no emission reduction equipment used) through four gravity stacks. These are simply open ducts leading from the hood over the furnace to the top of the building (no fans are used). Thus, gas flow rate depends directly on the temperature of the gas. Flow rates through the ducts are not constant and may vary independently among the ducts. Sampling by EPA Method 5 was done simultaneously in the primary system duct, after the scrubber, and in one of the four gravity stacks. A velocity traverse was also made in the two stacks on the opposite side of the furnace to determine flow rate through these stacks. The scrubber discharge water was sampled simultaneously with these tests using an automatic sampler.

Other samples taken at the plants included:

1. Samples of dust actually collected by the baghouses (all plants except the covered ferromanganese which uses no baghouse). These samples were collected to provide information on material actually going to land disposal and to provide a check on the actual amount of organic captured by the baghouse.
2. Wastewater treatment pond inlet and outlet samples were taken, with an automatic sampler, at the two plants using this treatment method (both plants with covered furnaces). These samples were analyzed for priority pollutants to assess the effectiveness of treatment.

3. Groundwater samples, up-gradient and down-gradient of the waste disposal area, were collected from the Ashtabula plant which had monitor wells installed. These samples were taken to determine if organics or heavy metals were leaching into the groundwater.

### 5.2.2 Sample Analysis

The filter catch and probe wash from the sampling train were weighed and in conjunction with gas flow rate, temperature, etc., were used to calculate particulate concentrations and total particulate mass. These samples and the impinger and XAD-2 catches were extracted with methylene chloride to remove the organic matter. All extracts were analyzed for BaP by thin layer chromatography (TLC) with fluorescence detection. This compound was detected in the previous study[6] and was considered, for the purposes of this report, to be a surrogate for polynuclear aromatic hydrocarbons (PAH). The analytical method used was as follows.

The methylene chloride extract was concentrated to 10 mL. A 1-mL aliquot was removed and total organic determined by evaporating the solvent and weighing the residue.[5] This method is equivalent to Level 1[5] Grav organics. The method recovers the high boiling point (>300°C) organics only. The remaining sample was solvent exchanged into cyclohexane. Fifty μL aliquots of the samples were spotted onto scribed, 20 x 20 cm, 200 micrometer, 20 percent acetated cellulose TLC plates with an automated multispotting device over a 14 minute period. The plate was held at 70°C. Alternate channels of the plate were spotted with BaP standards ranging from 0 to 1 μg BaP/mL. After air drying, the plates were examined in a uv light box to mark the regions of interest. The BaP fluorescence was then quantitated in a Schoeffel SD 3000 spectrodensitometer set up for fluorescence.

The machine was run in the reflectance mode. The reference beam was closed off and the balance control offset completely to the sample beam side. An excitation wavelength of 388 nanometers was used with a primary slit width of 1.1 nanometers and 0.5 nanometer slit setting. The machine monitored the emission wavelength of 430 nanometers (interference filter in detector housing). The SDC 300 density computer controls were placed in the single and numerator positions. The instrument output was recorded on a Honeywell

Electronik 196 recorder. Samples with indicated concentrations above 1 μg BaP/mL were diluted so that the final concentration was within the 0-1 μg BaP/mL range of the standards used and the analysis repeated.

Two samples, both composites of baghouse outlet runs, were sent to Stewart Laboratories, Inc. for GC/MS analysis with emphasis on PNAs.

Water samples collected from scrubbers were filtered to determine particulate concentration and both solid and aqueous phases extracted with methylene chloride to remove the organics. These data and measured water flow rates were used to calculate total mass. The extracts were analyzed for BaP as described above.

Samples of the inlet to and discharge from the wastewater treatment pond at two plants were split, with part of the sample being analyzed for priority pollutants by Stewart Laboratories and the balance filtered for suspended solids determination. The aqueous and solid phases were analyzed for organics and BaP as described above. The solid phase was also analyzed for As, Cd, Cr, Be, Hg, Pb, Sb, Se, and Th, extracted following EPA's Office of Solid Waste Procedures (40 CFR Part 261, May 19, 1980), and the leachate analyzed for the same metals.

The priority pollutant analyses were done using the following instrumentation: volatile organics, base/neutral extractables, and acid extractables were run on a Finnigan Model 4023 GC/MS with Incos data system; pesticides and PCBs were run on a Tracor Model 222 GC with $Ni^{63}$ electron capture and Tracor Model 700 Hall electrolytic conductivity detectors; metals were run on an Instrumentation Laboratory (IL) Model 151 atomic absorption spectrometer and on IL Model 455 Flameless Atomizer (graphite furnace).

Baghouse dust samples were analyzed by atomic absorption spectroscopy (AAS) for the metals listed above, extracted following EPA's Office of Solid Waste procedures, and the leachate analyzed for the same metals by AAS. The dusts were also extracted with methylene chloride and total organics and BAP determined.

# 6.0 TESTING OF FURNACE PRODUCING SILICON METAL

These tests were done on the No.2 furnace and baghouse at Interlake, Inc.'s plant in Selma, AL, January 26, 27, and 28, 1981.

## 6.1 SITE DESCRIPTION

### 6.1.1 General Plant

This plant is located adjacent to the Alabama River just southeast of Selma, AL. There are two furnaces at the plant, No.1 rated at 16 MW and No.2 rated at 17 MW, both of which produce silicon metal. Both furnaces are of the open type and use separate baghouses for emission reduction. There is, however, an interconnection in this ductwork that allows either or both baghouses to be connected to either or both furnaces. This connection was closed during the testing. There is an emergency bypass duct for furnace No.1 that allows furnace fumes to be exhausted directly to the atmosphere in the event of a failure at a baghouse. Hot metal tapped from the furnaces is further refined by oxygen injection into the ladle. Fumes from this operation are collected and ducted to the baghouse serving furnace No.1.

Fume collected by the baghouses is transported to a central storage hopper. The majority of this material is bagged and sold. The excess is placed in a pit on company property and wetted.

Raw materials and finished product are stored under covers.

### 6.1.2 Description: Furnace No.2 and Associated Pollution Capture Equipment

Testing was done on furnace No.2. This furnace was selected over No.1 simply because of accessibility to ductwork going to the baghouse and because fume from oxygen refining does not enter this system.

The furnace design input power rating is 17 MW. Power is supplied through three 1.14 meter (45 inch) diameter prebaked carbon electrodes. The furnace shell is designed to rotate. The electrodes remain stationary. There is a gap between the furnace mouth and the fume collecting hood (see Figure 1). This gap, which is about 2 meters (6 feet), allows air to be drawn into the area above the furnace mouth. Gases produced by the furnace reactions mix with this air and burn vigorously. The opening between the furnace mouth and the hood has been reduced by 50 percent by installing four plates, evenly spaced around the furnace, that extend from the furnace floor to the hood. This increases the air velocity at the hood mouth and increases the fume capture effectiveness. The openings which remain are sufficient to allow charging of premixed raw materials with a front-end loader and stoking (mixing) of material in the furnace.

There is one taphole in the furnace shell. A side draft hood is mounted on the furnace shell to collect tap fumes which are exhausted to the main hood through an opening in the furnace floor, above the taphole. There are also fans located in this area that force uncollected tap fume and other fugitives either directly out of the building or into the shed that covers the raw material. We estimated that the hood captured about 60 percent of the tap fume. The taphole is opened by firing 8 gauge metal slugs into the taphole plug. The molten alloy flows into a ladle positioned below the taphole. After the metal is removed from the furnace, blocks made of carbon paste are forced into the taphole to plug the hole.

Fumes collected from the furnace and taphole area enter the ductwork leading to the baghouse. The inside diameter of the duct is 2.79 meters (110 inches). The fume first passes (see Figure 1) through a "multiclone" collector which acts as a spark trap and also collects the larger sized particulates which are sold. The two exhaust fans are located after the multiclones. Each fan is equipped with an 800 horsepower motor and is designed to move 4390 $m^3$ (155,000 CFM) of air at 42 mm Hg and 204°C (22.5 inch W.C. and 400°F). The fans force the gas into the 12 compartment baghouse. Each baghouse compartment contains 1385 $m^2$ (14,905 $ft^2$) net cloth area for filtration--total 16,616 $m^2$ (178,860 $ft^2$). The filtered air rises through the compartment and is directed toward the center line of the building, by the sloping roof, where it is exhausted through a monitor. Bag cleaning is accomplished by sequentially isolating one compartment at a

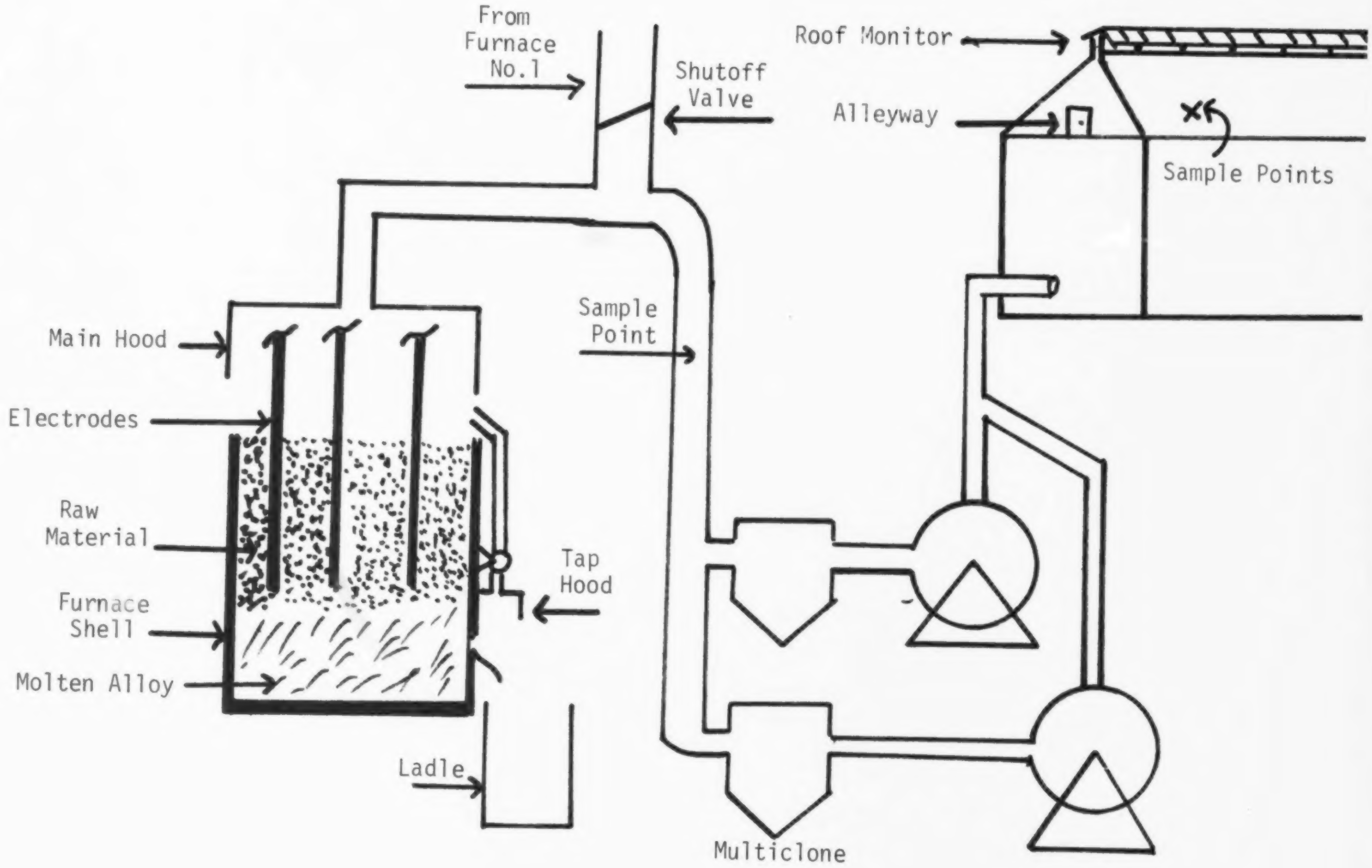
From Furnace No.1
Shutoff Valve
Roof Monitor
Alleyway
Sample Points
Main Hood
Electrodes
Raw Material
Furnace Shell
Molten Alloy
Sample Point
Tap Hood
Ladle
Multiclone

Figure 1. Schematic of furnace No.2 and associated pollution control equipment.

time deflating and then shaking the bags. The dust falls into the hopper and is conveyed to the central storage hopper.

## 6.2 PROCESS CONTROL

This furnace is used to produce high purity (> 98 percent) silicon. This is accomplished by mixing a silicon source (primarily gravel) with a reductant (carbon from coal, coke, woodchips, and electrode) and heating to a sufficiently high temperature to allow the primary reaction:

$$SiO_2 + 2C \rightarrow Si + 2CO$$

to occur. Heat for the process is supplied by the electric current passed through the raw materials. Woodchips, although supplying part of the carbon, are primarily used to maintain porosity in the furnace so that gases generated can escape. The silicon formed is in a molten state and collects in the bottom of the furnace. It is intermittently tapped from the furnace. Tapping normally begins at two hour intervals and can take up to one hour to complete.

The furnace operation can be controlled by adjusting the ratio of raw materials (response to this change is slow), or the power input. Power input can be varied by either changing the voltage or moving the electrodes vertically. Stoking is also important to operational stability.

## 6.3 TEST DESCRIPTION

Figure 1 is a schematic of furnace No.2 and the related pollution control equipment. Sample point locations are identified in this figure. Figures 2-4 give more detail on the sample point locations.

As shown, the inlet sample ports were located 90° apart in the 2.79 meters (110 inches) duct. The sample ports were located in the lower half of the duct, 45° from the vertical axis. The nearest flow disturbances were: upstream from sample point, 0.91 duct diameters; downstream from sample point, 0.69 duct diameters. Twenty-four points were sampled in each traverse axis (48 points total) for each test.

Ports for sampling the baghouse outlet were located in the compartment doors in the upper maintenance alleyway. The sampling probe was inserted

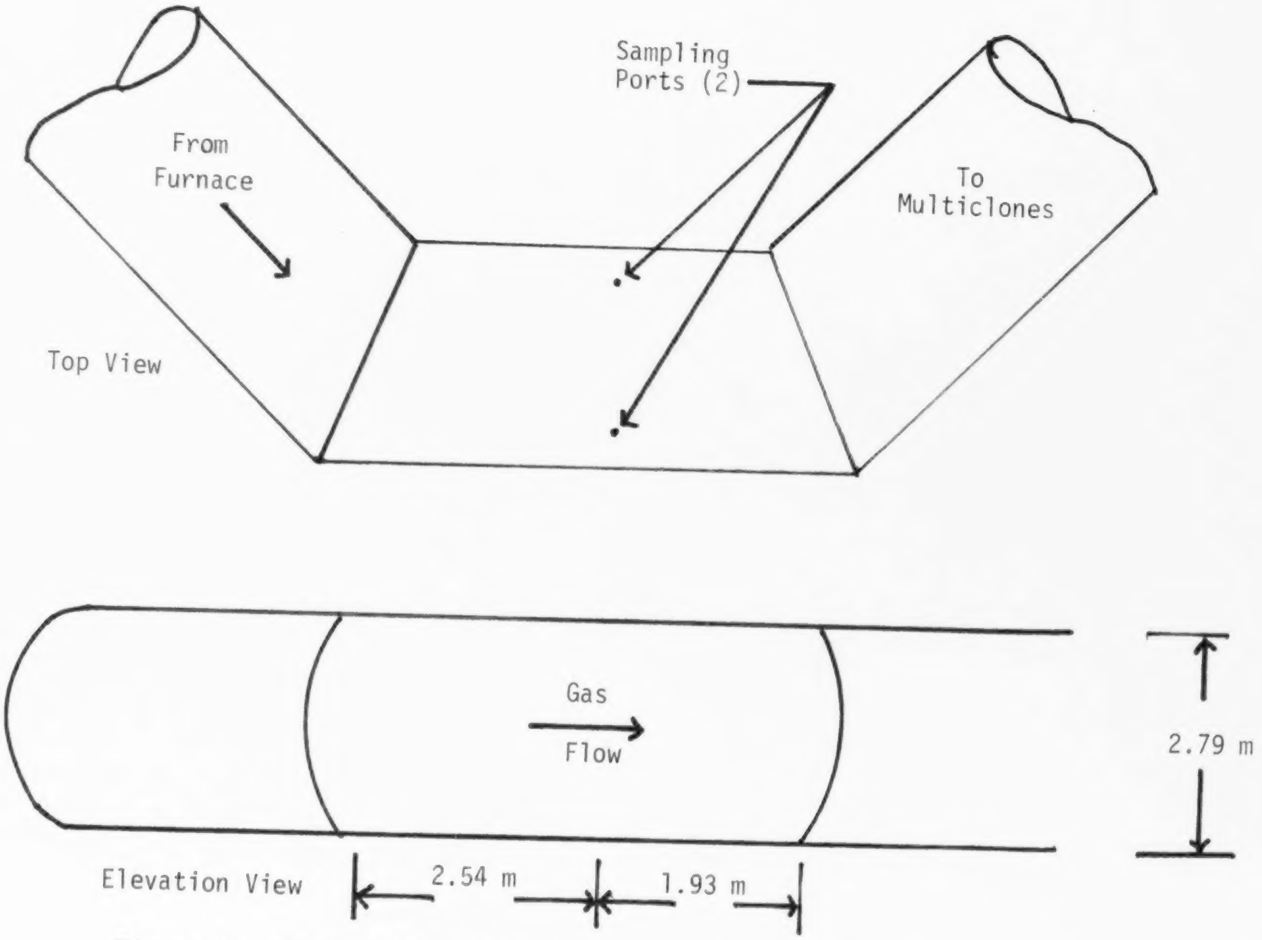
Sampling
Ports (2)
From
Furnace
To
Multiclones
Top View
Gas
Flow
2.79 m
Elevation View
2.54 m
1.93 m

Figure 2. Baghouse inlet duct dimensions and sample port locations.

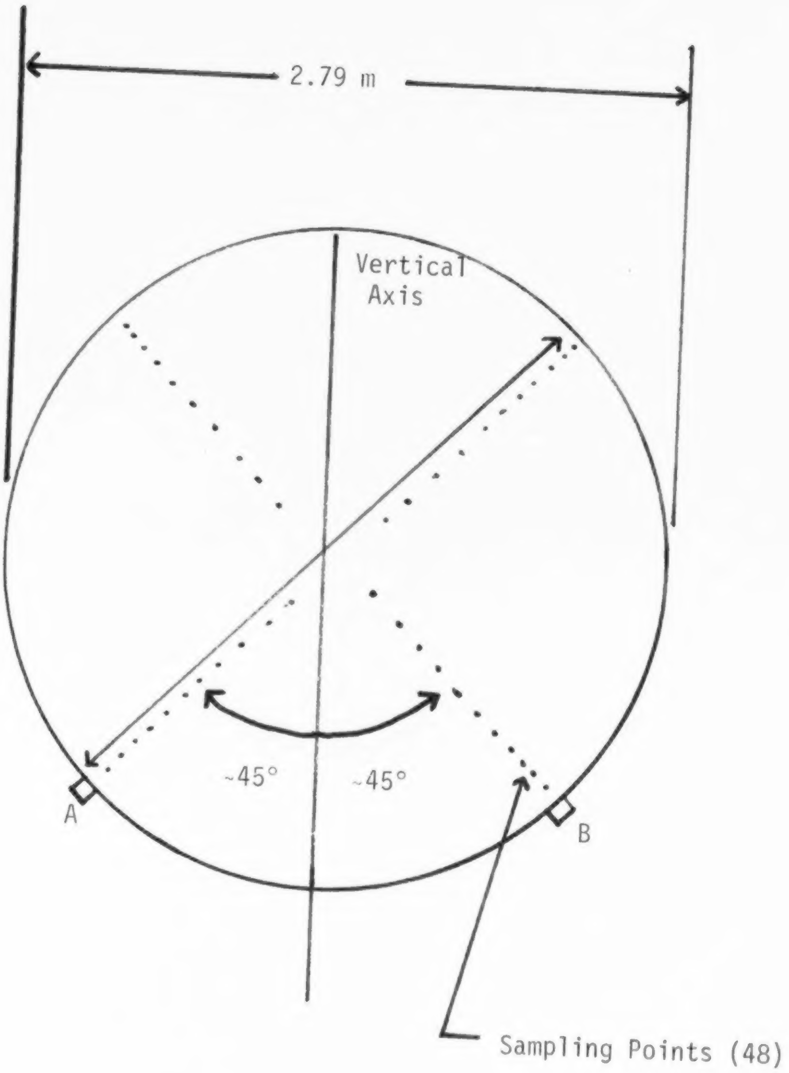
2.79 m
Vertical Axis
~45°
~45°
A
B
Sampling Points (48)

Figure 3. Inlet duct cross-section showing sampling points.

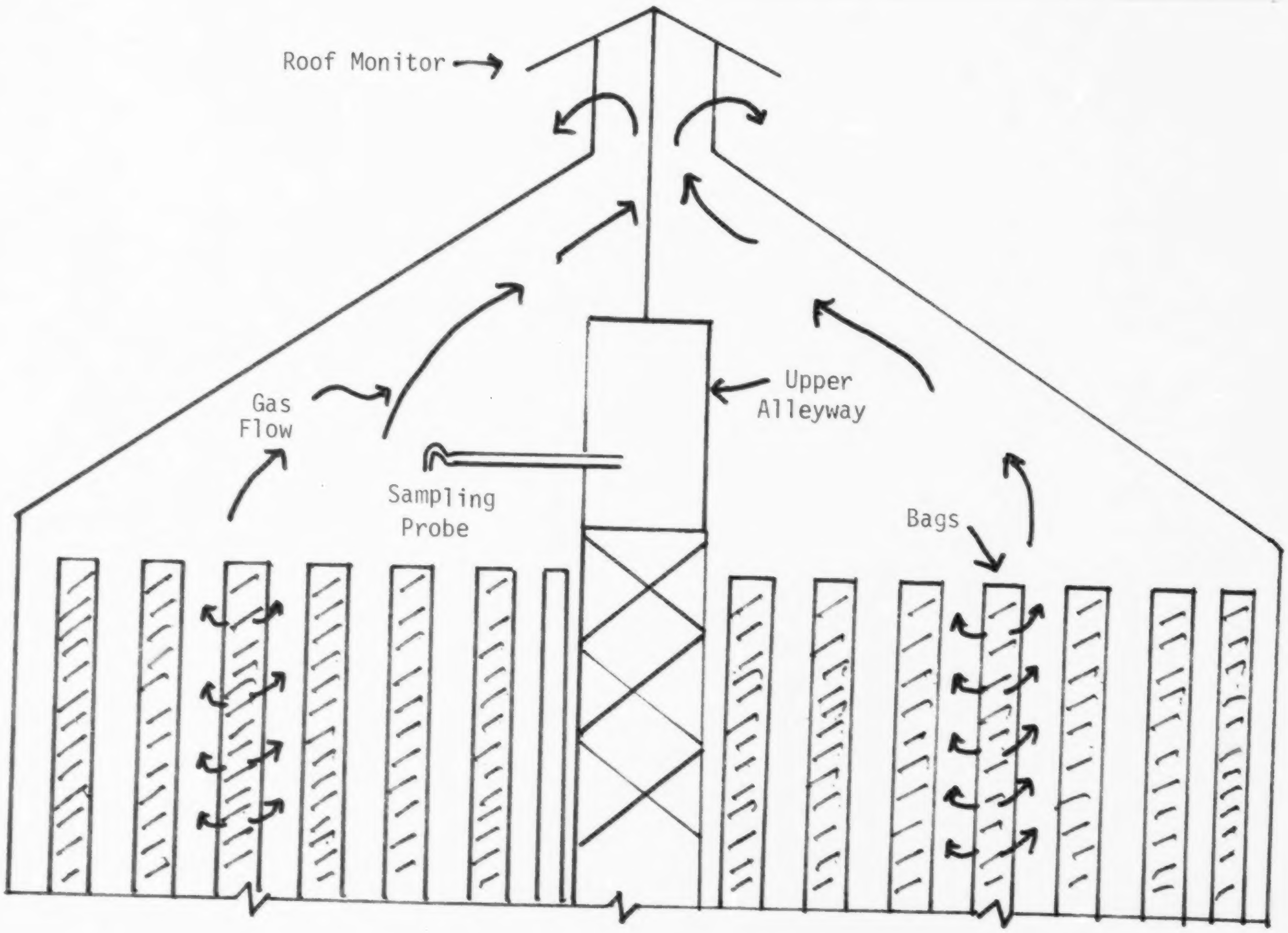
Roof Monitor
Gas Flow
Sampling Probe
Upper Alleyway
Bags

Figure 4. Elevation section of baghouse outlet showing sampling locations.

into the compartment about 2 meters (6 feet). Each compartment was sampled at only one point (no traverse). Four, of the 12 compartments, were sampled for each test. Each test was completed on a different set of four compartments.

Sampling at both locations was done by EPA Methods 1-5, as applicable, (see Appendix for details of Methods) with the following exceptions.

1. The sampling train was modified by inserting a cartridge, containing about 100 grams of XAD-2 resin, between the third and fourth impingers. The XAD-2 was used to capture organics passing through the filter.
2. With the exception of the first test, sampling at the baghouse outlet was not done isokinetically. Isokinetic sampling resulted in very low collection of gas (which would also result in low mass of particulate captured). Since the mean aerodynamic diameter of particulate escaping the baghouse was expected to be quite small (< 2 μm), it was felt that sampling at a higher (than isokinetic) rate would have minimal effect on the particulate concentration determined.
3. The sample train was cleaned with methylene chloride rather than acetone. This change was made to insure complete recovery of organics.
4. Methylene chloride was added to the impinger reagents during sample recovery. The impinger reagents were extracted, in the RTI laboratory, for organic recovery.

Simultaneously with the sampling activity, process operating information was also collected. This included:

1. Raw materials charged to the furnace -- from plant records.
2. Furnace power consumption -- instantaneous, read from meters in the control room, and cumulative, read from meters in the control room and at the power substation.
3. Weight of alloy produced and chemical analysis -- from plant records.
4. Time and duration of tapping.
5. Furnace operating conditions.
6. Baghouse power consumption -- from meter at power substation.
7. Baghouse compartment pressures.

Given in Tables 20 and 21 are the pertinent sampling data for the baghouse inlet and outlet. The outlet gas flow rate from the baghouse was calculated using inlet gas flow rate and temperature, ambient temperature (15.5°C-60°F), and baghouse exhaust gas temperature. Based on these measurements, about 32 percent of the baghouse exhaust gas is ambient air drawn in through the baghouse grates.

Given in Table 22 are the raw material consumption and alloy production data. Electrode consumption is not included because determining this value over a short time period is highly inaccurate. For those wishing to include electrode consumption, a value of about 10.3 Kg/MW-hr is appropriate. The data are given for all three shifts each day although testing occurred only during daylight hours. This allows a comparison of operations over the testing period. It is easy to see that the amount of alloy tapped on a shift basis does not correlate well with the amount of raw material fed to the furnace. For this reason, calculation presented later on a Mg of alloy produced basis are based on a 24 hour production basis.

Given in Table 23 are the times at which tapping occurred while testing was in progress and the product analysis. As can be seen, there was little variation in the product produced during the test period.

Given in Table 24 are the various meter readings for power consumed by the furnace and the baghouse. All readings given were taken at the power substation; the plant reported that the meters in the control room were slightly in error. The last digit presented for each reading was estimated from the dial type meter. Thus comparison of meter readings over short time periods may indicate a wider variation in power consumption than actually occurred. Chart recorders in the control room showed that the rate of power consumption was very stable over the test period and was always between 16.0 and 18.5 MW.

Given in Table 25 are the overall baghouse pressure differentials recorded during the test period. These ranged from 6.5 to 13.1 mm of Hg (3.5 to 7.0 inches of $H_2O$). We note no particular trends for this data other than that the differential pressure was somewhat higher late in the afternoon than in the morning and that the average pressure drop was greater on 1/27 and 1/28 than on 1/26.

TABLE 20. BAGHOUSE INLET SAMPLING DATA

| Run No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Date | 1/26/81 | 1/27/81 | 1/27/81 | 1/28/81 | 1/28/81 | 1/28/81 |
| Start Time | 1335 | 0913 | 1400 | 0830 | 1120 | 1400 |
| Stop Time | 1525 | 1201 | 1545 | 1017 | 1322 | 1600 |
| Net Sampling Time, min | 96 | 96 | 96 | 96 | 96 | 96 |
| Stack Temperature, °C | 161 | 153 | 158 | 149 | 153 | 158 |
| Stack Flow Rate dsm$^3$/min[a] | 7,272.9 | 7,747.9 | 7,478.2 | 7,650.9 | 7,712.1 | 7,823.9 |
| Stack Flow Rate A m$^3$/min[b] | 11,152 | 11,564 | 11,409 | 11,257 | 11,561 | 11,753 |
| Volume Collected dsm$^3$[a] | 0.7888 | 1.7917 | 0.8153 | 0.8389 | 0.8637 | 0.8585 |
| Percent Isokinetic | 99.7 | 98.4 | 100.2 | 100.8 | 103.0 | 100.9 |

[a] Moisture free and at 20°C and 76.0 cm Hg.

[b] Actual flow rate at stack conditions.

TABLE 21. BAGHOUSE OUTLET SAMPLING DATA

| Run No.<br>Date | 1<br>1/26/81 | 2<br>1/27/81 | 3<br>1/27/81 | 4<br>1/28/81 | 5<br>1/28/81 |
|---|---|---|---|---|---|
| Start Time | 1330 | 0935 | 1358 | 0826 | 1240 |
| Stop Time | 1627 | 1236 | 1659 | 1139 | 1531 |
| Net Sampling Time, min | 160 | 160 | 160 | 160 | 160 |
| Stack Temperature, °C | 119 | 120 | 108 | 98 | 113 |
| Volume Collected $dsm^{3}$[a] | 1.0173 | 1.2544 | 3.2559 | 3.3476 | 3.2185 |
| Gas Flow Rate $dsm^{3}$[b] /min | 10,670 | 11,380 | 10,980 | 11,230 | 11,400 |
| Compartments Sampled | 4,5,11,12 | 2,3,9,10 | 1,6,7,8 | 1,2,7,8 | 4,5,11,12 |

[a] Moisture free and at 20°C and 76.0 cm Hg.

[b] Estimated using enthalpy balance based on measured inlet flow rate, ambient temperature, inlet gas temperature, and outlet gas temperature.

TABLE 22. RAW MATERIAL CONSUMPTION AND PRODUCT PRODUCED (in kg)

| Date | 1/26/81 | 1/26/81 | 1/26/81 | 1/27/81 | 1/27/81 | 1/27/81 | 1/28/81 | 1/28/81 | 1/28/81 |
|---|---|---|---|---|---|---|---|---|---|
| Shift | 11-7 | 7-3 | 3-11 | 11-7 | 7-3 | 3-11 | 11-7 | 7-3 | 3-11 |
| Gravel | 25,855 | 17,917 | 31,298 | 26,082 | 25,628 | 31,398 | 27,216 | 29,484 | 32,205 |
| Woodchips | 21,137 | 15,604 | 25,038 | 20,820 | 20,775 | 25,038 | 21,772 | 23,587 | 25,764 |
| Coal No.1 | 4,525 | 2,889 | 5,164 | 4,266 | 4,191 | 5,164 | 4,491 | 4,962 | 5,475 |
| Coal No.2 | 2,456 | 1,574 | 2,817 | 2,327 | 2,286 | 2,817 | 2,449 | 2,751 | 3,059 |
| Pet Coke | 2,585 | 1,724 | 3,130 | 2,585 | 2,540 | 3,130 | 2,722 | 2,948 | 1,932 |
| Total Raw Materials | 56,558 | 39,708 | 67,447 | 56,080 | 55,420 | 67,447 | 58,650 | 63,732 | 69,724 |
| Total Product (Tap Weights) | 9,144 | 9,891 | 10,561 | 10,314 | 10,299 | 9,870 | 9,678 | 10,190 | 10,229 |

## TABLE 23. FURNACE TAPS AND TAP ANALYSIS[a]
## (For Taps Occurring During Testing)

| Date | Tap Time | % Si | % Fe | % Ca | % Al |
|---|---|---|---|---|---|
| 1/26/81 | 1414 - 1456 |  | 0.36 | 0.10 | 0.25 |
|  | 1615 - 1700 |  | 0.50 | 0.15 | 0.31 |
|  | Average for day | 98.92 | 0.44 | 0.11 | 0.28 |
| 1/27/81 | 1017 - 1055 |  | 0.35 | 0.19 | 0.34 |
|  | 1214 - 1258 |  | 0.36 | 0.21 | 0.37 |
|  | 1407 - 1455 |  | 0.53 | 0.26 | 0.37 |
|  | 1615 - 1655 |  | 0.43 | 0.27 | 0.40 |
|  | Average for day | 98.84 | 0.45 | 0.15 | 0.31 |
| 1/28/81 | 1015 - 1055 |  | 0.56 | 0.22 | 0.40 |
|  | 1215 - 1255 |  | 0.44 | 0.23 | 0.39 |
|  | 1420 - 1455 |  | 0.67 | 0.24 | 0.34 |
|  | Average for day | 98.76 | 0.53 | 0.14 | 0.32 |

[a] After oxygen treating.

## TABLE 24. POWER CONSUMPTION RECORD
## POWER STATION METER READINGS,[a] MW-hr

| Date | Time | Furnace No.2 | Baghouse No.2 |
|---|---|---|---|
| 1/26/81 | 1315 | 42,198 | 313.8 |
| | 1428 | 42,220 | 315.8 |
| | 1514 | 42,231 | 316.9 |
| | 1549 | 42,241 | 317.8 |
| | 1707 | 42,268 | 319.8 |
| | Average Load | 18.1 MW hr/hr | 1.55 MW hr/hr |
| 1/27/81 | 0812 | 42,517 | 343 |
| | 0944 | 42,541 | 345.3 |
| | 1026 | 42,554 | 346.7 |
| | 1106 | 42,568 | 347.8 |
| | 1354 | 42,612 | 352 |
| | 1531 | 42,640 | 354.1 |
| | 1632 | 42,658 | 356 |
| | 1716 | 42,671 | 357.1 |
| | Average Load | 17 MW hr/hr | 1.56 Mw hr/hr |
| 1/28/81 | 0723 | 42,909 | 379.1 |
| | 0830 | 42,926 | 381 |
| | 0940 | 42,947 | 382.6 |
| | 1018 | 42,958 | 383.5 |
| | 1112 | 42,972 | 385 |
| | 1207 | 42,989 | 386.8 |
| | 1321 | 43,009 | 388.6 |
| | 1421 | 43,025 | 390.2 |
| | 1504 | 43,038 | 391.2 |
| | 1544 | 43,052 | 392.5 |
| | Average Load | 17.1 MW hr/hr | 1.60 MW hr/hr |

Furnace No.2 Meter Readings Taken by Plant Personnel
(at Power Station)

| Date | Time | Meter Reading in 10's of Mw-hr | MW-hr Consumed, day |
|---|---|---|---|
| 1/25/81 | 2300 | 4195 | |
| 1/26/81 | 2300 | 4235 | 400 |
| 1/27/81 | 2300 | 4275 | 400 |
| 1/28/81 | 2300 | 4316 | 410 |

[a] The last digit for both meter readings was estimated from the dial-type meter. Thus comparison of meter reading over short time periods may indicate a wider variation in furnace power consumption than actually occurred. The furnace power consumption was always between 16.0 and 18.5 MW during the course of the testing.

## TABLE 25. BAGHOUSE PRESSURE DIFFERENTIAL[a]

| 1/26/81 | | 1/27/81 | | 1/28/81 | |
|---|---|---|---|---|---|
| Time | $\Delta P$[b] | Time | $\Delta P$[b] | Time | $\Delta P$[b] |
| 1330 | 7.1 (3.8) | 0920 | 8.4 (4.5) | 0740 | 7.1 (3.8) |
| 1345 | 7.8 (4.2) | 0940 | 8.8 (4.7) | 0825 | 7.8 (4.2) |
| 1403 | 6.5 (3.5) | 1055 | 11.0 (5.9) | 1007 | 7.8 (4.2) |
| 1420 | 7.1 (3.8) | 1116 | 10.3 (5.5) | 1050 | 9.0 (4.8) |
| 1446 | 9.0 (4.8) | 1200 | 10.5 (5.6) | 1123 | 10.5 (5.6) |
| 1503 | 7.8 (4.2) | 1245 | 10.8 (5.8) | 1147 | 7.8 (4.2) |
| 1517 | 7.1 (3.8) | 1340 | 9.0 (4.8) | 1240 | 10.3 (5.5) |
| 1547 | 7.1 (3.8) | 1410 | 9.2 (4.9) | 1330 | 7.8 (4.2) |
| 1624 | 9.2 (4.9) | 1440 | 13.1 (7.0) | 1440 | 11.2 (6.0) |
| | | 1520 | 11.2 (6.0) | 1515 | 13.1 (7.0) |
| | | | | 1710 | 13.1 (7.0) |

[a] Pressure difference between gas going into baghouse and gas leaving baghouse.

[b] $\Delta P$--pressure differential given in mm of Hg. Numbers in parentheses are inches of $H_2O$.

## 6.4 TEST RESULTS

### 6.4.1 Gas Analysis

During Run No.1 at the baghouse inlet (1/26/81, 1335-1525), a gas sample was collected and an Orsat gas analysis performed. The results are given below.

ORSAT GAS ANALYSIS, BAGHOUSE INLET

| Component | Percent, by volume+ |
|---|---|
| $N_2$ | 78.4 |
| $O_2$ | 20.3 |
| $CO_2$ | 1.2 |
| CO | 0.1 |

+Dry basis.

These data suggest that fairly complete combustion of the furnace gas is occurring. The furnace gases burn above the surface of the raw material charged into the furnace. They also show that a large volume of ambient air, relative to the volume of gas produced by the furnace, is drawn into the fume collection system. The gas analysis is almost the same as ambient air.

### 6.4.2 Particulates

Given in Table 26 are the results obtained for particulate matter in the baghouse inlet gas. The particulate concentration in the gas averaged about 1240 mg/dsm$^3$ for the six runs with an approximate range of 700-2000 mg/dsm$^3$. Total particulate generated by the furnace averaged 567 Kg/hour, again with a wide range. In terms of operating parameters, the average amount of particulate generated was about 33 Kg/MW-hr, 77 Kg/Mg raw material feed, or 446 Kg/Mg alloy produced (tap weights).

## TABLE 26. PARTICULATE, BAGHOUSE INLET

| Run Number | mg Captured | Concentration[a] in Gas, $mg/dsm^3$ | Generated[b] per hour, Kg | Average Load[c] During test MW-hr/hr | Kg Generated[d] per MW-hr | Kg Generated[e] per Mg Feed | Kg Generated[f] per Mg Alloy |
|---|---|---|---|---|---|---|---|
| 1 | 553.2 | 701.3 | 306.0 | 16.75 | 18.27 | 52.2 | 247 |
| 2 | 2,267.0 | 1,265.3 | 588.2 | 16.67 | 35.28 | 84.9 | 463 |
| 3 | 1,460.6 | 1,791.5 | 803.8 | 17.47 | 46.01 | 106.2 | 604 |
| 4 | 672.5 | 801.6 | 368.0 | 17.78 | 20.70 | 50.2 | 282 |
| 5 | 725.6 | 840.1 | 388.7 | 17.21 | 22.59 | 53.0 | 308 |
| 6 | 1,734.0 | 2,019.8 | 948.2 | 18.07 | 52.47 | 118.2 | 715 |
| Average/all runs | | 1,236.6 | 567.2 | | 32.55 | 77.5 | 436 |

[a] Calculated by dividing mg captured by sample volume collected (see Table 20).

[b] Calculated by multiplying concentration in gas (in $Kg/dsm^3$) by gas flow rate during test (see Table 20).

[c] Calculated by using last meter reading before test start and first meter reading after test stop (see Table 24).

[d] Calculated by dividing Kg generated/hr by average load during test.

[e] Average Mg of feed was calculated as follows: total mix fed on each shift was divided by the operating hours on that shift to give average amount of mix fed per hour on that shift. When a test was completed entirely on one shift, the total particulate generated per hour was divided by the average mix fed per hour to give Kg particulate generated per Mg feed. This occurred in Runs 2, 4, and 5. When the test period overlapped two shifts, the average mix fed per hour on each shift was multiplied by the percentage of the test time occurring on that shift. The numbers were then summed to give the average mix feed per hour during the test.

[f] Since the amount of product tapped, for any individual tap, may vary from the actual amount produced between taps, the total amount tapped for the day was used for calculation. Total product tapped was divided by total MW-hr consumed to give Mg product/MW-hr. This was multiplied by the average MW load during test to give Mg product/hr during testing. This was then divided into Kg particulate generated/hr to give Kg particulate per Mg product (tapped).

Considering the variability of the data in Table 26, it seems obvious that particulate generation is strongly influenced by factors other than power input, amount of raw material fed, or amount of alloy tapped. Particulate captured during tapping also is unlikely to be responsible for the variability observed. One full tapping cycle was included in all runs except No.4. Although the results for Run No.4 are below the mean, they are not the lowest obtained.

The process observers notes were examined to see if any activity at the furnace correlated with the increased particulate generation. Although both raw material charging and furnace stoking seem visually to temporarily cause heavier than normal fuming, they do not correlate with the particulate results. Tapping fumes, which appeared to be quite heavy at the furnace, also did not correlate. The frequency and vigorousness of "blows" from the electrode area did, however, correlate. "Blows" are jets of extremely hot gas that issue from the high temperature reaction region and flow upward around the electrodes at high velocity. This is caused primarily by the furnace charge not descending uniformly into the reaction area around the electrodes.

During Run No.1, made the afternoon of 1/26/81, the furnace was operating very smoothly with virtually no "blows." The lowest particulate generation rates for the six tests were obtained during this run. Runs No.2 and 3 were made the morning and afternoon of 1/27/81, respectively. The observers report the furnace was running "a little rough with occasional light blows." Particulate results obtained were higher than the six run average. Runs No.4, 5, and 6 were made on 1/28/81. For the first two runs that day, the furnace was running quite smoothly with only an occasional light "blow." Particulate results obtained were below the six run average. Furnace operations became increasingly rough during the course of Run No.6. During most of the run, fume generation appeared visually to be heavier than normal. During the last 30 minutes (25 percent of test time) fume generation was judged to be very heavy with vigorous "blows" fairly often. The highest particulate results for the six tests were obtained during this run.

It should be pointed out that in the judgment of the plant furnace operators, none of the above described furnace conditions are unusual. Thus, the six tests performed encompassed periods of very smooth up to and including significantly rough furnace performance, all of which fall within the range of normal operation. The six run average, therefore, should represent a fairly good approximation of the average particulate generation rate for this furnace.

Given in Table 27 are the particulate results for the baghouse exhaust. The average particulate concentration in the gas emitted was about 31 mg/dsm$^3$, with a range of 5.2 to 75.5 mg/dsm$^3$. The average amount of particulate emitted was 21.2 Kg/hour with a range of 3.3 to 50.9 Kg/hour. In terms of operating parameters, particulate emitted averaged 1.22 Kg/MW-hr, 2.87 Kg/Mg raw material fed, and 16.5 Kg/Mg alloy produced (tap weights).

Given in Table 28 are the calculated baghouse particulate capture efficiencies for the runs made. It should be noted that the plant had completed a thorough inspection and maintenance on the baghouse just prior to these tests. It is obvious from the data that the baghouse particulate capture efficiency was significantly lower for outlet Runs No.4 and 5 than for the preceding three runs. During the first two days of testing, (when outlet Runs No.1, 2, and 3 were made), the baghouse performed quite well. There were essentially no visible emissions and no evidence of bag failure. However, on the third day, when outlet Runs No.4 and 5 were made, bags failed in compartments 6, 8, and 9 (about 12:45). None of these compartments were being tested at the time of bag failure. It is highly probable, however, that bags in several compartments had begun to leak (prior to complete failure) but not seriously enough to warrant compartment shutdown and bag replacement. (Run No.4, which preceded bag failure, was for compartments 1, 2, 7, and 8). No complete bag failure was observed in the compartments tested during Run No.5 (4, 5, 11, and 12). However, the relatively high rate of emission would indicate some of the bags were probably leaking. This scenario (no-or- few bags leaking after maintenance, bags begin to leak, then bag failure) is probably typical of the baghouse operation. Therefore, the average particulate collection efficiency for the five tests should be used rather than the measured efficiency for any particulate test.

TABLE 27. PARTICULATE, BAGHOUSE OUTLET[a]

| Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Emitted per hour Kg | Average Furnace Load During Test MW-hr/hr | Emitted per MW-hr Kg | Emitted per Mg Feed Kg | Emitted per Mg Alloy Kg |
|---|---|---|---|---|---|---|---|
| 1 | 5.3 | 5.2 | 3.3 | 18.10 | 0.18 | 0.49 | 2.5 |
| 2 | 16.3 | 13.0 | 8.9 | 16.67 | 0.53 | 1.28 | 7.0 |
| 3 | 25.5 | 7.8 | 5.1 | 17.52 | 0.29 | 0.64 | 3.8 |
| 4 | 252.6 | 75.5 | 50.9 | 17.42 | 2.92 | 6.94 | 39.8 |
| 5 | 177.7 | 55.2 | 37.8 | 17.42 | 2.17 | 4.99 | 29.6 |
| Average All Tests |  | 31.3 | 21.2 |  | 1.22 | 2.87 | 16.5 |

[a] See notes Table 26 for calculation methods.

TABLE 28. BAGHOUSE PARTICULATE CAPTURE EFFICIENCIES

| Outlet Run Number | Inlet Run Number Used in Calculation | Baghouse System[a] Particulate Capture Efficiency |
|---|---|---|
| 1 | 1 | 98.9 |
| 2 | 2 | 98.5 |
| 3 | 3 | 99.4 |
| 4 | 4 | 86.2 |
| 5 | 5, 6[b] | 94.3 |
| Average (all runs) | | 96.3 |

[a] Calculated using Kg generated and Kg emitted per hour. Comparisons based on particulate concentration in the gases will overstate baghouse efficiency because of additional air drawn into baghouse through the cooling air grates. System includes multiclone precollectors and baghouse.

[b] A Simple average of the particulate generated in Runs No.5 and 6 was used--outlet Run No.5 overlapped both inlet Runs No. 5 and 6.

Federal New Source Performance Standards (NSPS), which incidentally are not applicable to any furnace in the ferroalloy industry, limit emission from furnaces producing silicon metal to 0.45 Kg/MW-hr. The five run average for this furnace was 1.22 Kg/MW-hr. Two of the runs were below 0.45 Kg/MW-hr; one slightly exceeded this limit; and two significantly exceeded the NSPS limit.

Based on the test data, about 13,100 Kg (14.4 tons) of particulate was captured by the baghouse system (including multiclone precollector) for a 24 hour operating period.

### 6.4.3 Organic Matter

Given in Table 29 are the results obtained for organic matter in the baghouse inlet. The weight of organic capture was determined by evaporating (at room temperature) aliquots of the methylene chloride extracts of probe rinses, filter catches, and XAD-2 resins. It is recognized that this

## TABLE 29. ORGANICS, BAGHOUSE INLET

| Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Generated per hour, Kg | Generated per MW-hr, Kg | Generated per Mg Feed, Kg | Generated per Mg Alloy, Kg |
|---|---|---|---|---|---|---|
| 1 | 110 | 139 | 60.9 | 3.63 | 10.4 | 49.1 |
| 2 | 83 | 46.3 | 21.5 | 1.29 | 3.11 | 17.0 |
| 3 | 88 | 108 | 48.4 | 2.77 | 6.40 | 36.4 |
| 4 | 91 | 108 | 49.8 | 2.80 | 6.79 | 38.2 |
| 5 | 102 | 118 | 54.6 | 3.18 | 7.45 | 43.3 |
| 6 | 71 | 82.7 | 38.8 | 2.15 | 4.84 | 31.6 |
| Average, all runs | | 100 | 45.7 | 2.64 | 6.50 | 35.9 |

technique results in partial loss of volatile organics. Over 90 percent of the organic was found in the XAD-2 resin. Very little of the organic was adsorbed on the particulates.

The concentration in the baghouse inlet gas averaged 100 mg/dsm$^3$ for the six runs, with a range of 46 to 139 mg/dsm$^3$. Total organic generated by the furnace averaged 45.7 Kg/hour, with a range of 21 to 61 Kg/hour. Thus, the furnace was generating about 8 percent as much organic matter as particulates. In terms of operating parameters, the average amount of organic matter generated was 2.64 Kg/MW-hr, 6.5 Kg/Mg raw material fed, or 36 Kg/Mg alloy produced (tap weight).

The organic generation rate does not correlate well with any of the measured process parameters or with other process observations, including the incidence and severity of furnace blows. The data do suggest, however, that less organic matter is generated during periods of frequent furnace blows. This would be expected since flame temperature is very high during the blow.

Given in Table 30 are the organic results for the baghouse exhaust. The average concentration in the gas was 53 mg/dscm$^3$ (for the three runs where complete data are available). The average amount emitted for the three tests was 34 Kg/hour, with a range of 16 to 71 Kg/hour. In terms of operating parameters, the average amount emitted was 1.9 Kg/MW-hr, 4.9 Kg/Mg feed, or 26 Kg/Mg alloy tapped. It is obvious that run No.1, with an emission rate two times the average and four times the rate for runs No.3 or 4, dominate the overall average. A review of both process and sampling information revealed no clear explanation for this value. Thus, even though the results show a greater amount of organic exiting the baghouse than in the baghouse inlet we believe the results are correct. (Note that the outlet sample was taken for an additional hour after completing the inlet run. The results obtained suggest that the organic generation rate was greater in this last hour than measured during the inlet test.) It is interesting to note that the organic emission rate for the three runs is greater than the particulate emission rate (average of all five runs or runs 1, 3, and 4 only). If only runs No.3 and 4 are compared, the organic emission rate is 57 percent of the particulate emission rate.

## TABLE 30. ORGANICS, BAGHOUSE OUTLET

| Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Emitted per hour, Kg | Emitted per MW-hr, Kg | Emitted per Mg Feed, Kg | Emitted per Mg Alloy, Kg |
|---|---|---|---|---|---|---|
| 1 | 113 | 111.1 | 71.1 | 3.93 | 10.5 | 53.1 |
| 2 | Sample lost in analysis | | | | | |
| 3 | 78 | 24.0 | 15.8 | 0.91 | 1.99 | 11.8 |
| 4 | 80 | 23.9 | 16.1 | 0.92 | 2.20 | 12.6 |
| 5 | Sample lost in analysis | | | | | |
| Average, Runs 1,3, & 4 | | | | | | |

Given in Table 31 is the calculated baghouse capture efficiency for the organic matter. The overall average is obviously dominated by the negative capture determined in test run No.1. The remaining two runs indicate an average capture of about 68 percent. Most (70 percent or greater) of the organic in the baghouse emission was found in the XAD-2 resin indicating that the organic was in the vapor phase and not adsorbed on the particulate. Thus, it is unlikely that increasing the particulate capture efficiency of the baghouse would have much effect on organic emissions.

TABLE 31. BAGHOUSE ORGANIC CAPTURE EFFICIENCY

| Run Number | Capture Efficiency, % |
|---|---|
| 1 | -16.7 |
| 3 | 67.4 |
| 4 | 67.7 |
| Average | 39.5 |

### 6.4.4 Benzo(a)Pyrene

Given in Table 32 are the results obtained for benzo(a)pyrene (BaP) in the baghouse inlet. BaP was detected in four of the six runs. Two of the runs (1 and 5) were only slightly above the detection limit of the method used (about 0.5 $\mu g/m^3$). The average BaP concentration in the gas was 0.77 $\mu g/dsm^3$ or about $8 \times 10^{-4}$ percent of the total organic found. For the four runs in which BaP was detected, about 40 percent of the BaP was adsorbed on the particulates. This varied, however, from zero (runs 1 and 5) to 100 percent (run 6). The average amount of BaP generated per hour by the furnace was 0.36 grams. In terms of operating parameters, the averages were 0.021 g/MW-hr, 0.05 g/Mg feed, 0.28 g/Mg alloy tapped.

Given in Table 33 are the BaP results obtained for the baghouse outlet. Since part of the samples collected in runs 2 and 5 were lost during analysis, only runs 1, 3, and 4, provide useful data. It should be pointed

TABLE 32. BaP, BAGHOUSE INLET

| Run Number | μg Captured | Concentration in Gas, $\mu g/dsm^3$ | Generated per hour, gms | Generated per MW-hr, gms | Generated per Mg Feed, gms | Generated per Mg alloy, gms |
|---|---|---|---|---|---|---|
| 1 | 0.6 | 0.76 | 0.33 | 0.020 | 0.056 | 0.27 |
| 2 | 2.5 | 1.4 | 0.65 | 0.039 | 0.094 | 0.51 |
| 3 | ND | - | - | - | - | - |
| 4 | ND | - | - | - | - | - |
| 5 | 0.7 | 0.81 | 0.38 | 0.022 | 0.052 | 0.30 |
| 6 | 1.4 | 1.63 | 0.77 | 0.046 | 0.096 | 0.63 |
| Average |  | 0.77 | 0.36 | 0.021 | 0.050 | 0.28 |

ND = None detected--detection limit 0.5 μg.

TABLE 33. BaP, BAGHOUSE OUTLET

| Run Number | μg Captured | Concentration in Gas, μg/dsm$^3$ | Emitted per hour, gms | Emitted per MW-hr, gms | Emitted per Mg Feed, gms | Emitted per Mg Alloy, gms |
|---|---|---|---|---|---|---|
| 1 | ND | - | - | - | - | - |
| 2[a] | ND? | - | | | | |
| 3 | 2.1 | 0.64 | 0.42 | 0.024 | 0.054 | 0.32 |
| 4 | ND | - | - | - | - | - |
| 5[a] | ND? | | | | | |
| Average Runs 1, 3, & 4 | | 0.21 | 0.14 | 0.008 | 0.018 | 0.11 |

[a] Part of these samples were lost during analysis (either XAD resin or particulate extract). No BaP was detected in the remaining part of the sample.

out, however, that no BaP was found in the remaining parts of runs 2 and 5 samples. No BaP was found in two of the three usable runs. The BaP content in run No.3 was about four times the method detection limit. We cannot explain why no BaP was found in inlet run No.3. The average BaP concentration in emitted gas for the three runs was 0.21 $\mu g/dsm^3$.

The total amount of BaP emitted per hour was 0.14 grams (about 39 percent of baghouse inlet values). In terms of operating parameters the average (for runs 1, 3, and 4) amount of BaP emitted was 0.008 g/MW-hr, 0.018 g/Mg feed, or 0.11 g/Mg alloy tapped.

Although the quantities of BaP emitted are quite small (tenths of a gram per hour), it must be remembered that BaP is a powerful carcinogen. It is appropriate, therefore, that this result should be called to the attention of the various regulatory officials.

### 6.4.5 BaP in Baghouse Collected Particulates

A sample was obtained of the particulate matter collected by the baghouse. In addition to leaching tests (discussed later), the sample was analyzed for BaP content. The dust contained 0.16 $\mu g$ BaP/g dust. The plant bags and sells the dust.

### 6.4.6 Leaching Test, Baghouse Dust

The baghouse dust was analyzed (by atomic absorption spectroscopy-AAS) for nine metals on EPA's Priority Pollutant list. At least four (Cd, Cr, Pb, and Se) of the metals are present (see Table 34) in concentrations which may be cause for some concern. Arsenic may also be of some concern but we cannot state this with confidence because of analytical interference.

The dust was subjected to leaching following procedures given in the Federal Register 40 CFR Part 261, Appendix II, May 19, 1980. The leachate analysis is given in column 3 of Table 34. None of the metals equal or exceed the permissible concentrations given in 40 CFR Part 261.24. Thus, on this basis the solid is nonhazardous.

Given in the last columns of the table are the actual amount of the element leached out of the solid and the percentage of the element extracted.

TABLE 34. LEACHING TESTS, SILICON METAL FURNACE BAGHOUSE DUST

| Element | Concentration in Original μg/g Solids | Concentration in Leachate mg/L | Permissible[b] Concentration mg/L | Amount Leached μg/g Solids | % of Element |
|---|---|---|---|---|---|
| Antimony | $<4.6 \times 10^{-2}$ | $<1.41 \times 10^{-2}$ | NS[c] | 0.281 | ? |
| Arsenic[a] | 16.9 | 1.29 | 5.0 | 25.8 | ? |
| Beryllium | $3.5 \times 10^{-2}$ | $<3 \times 10^{-5}$ | NS[c] | $<6 \times 10^{-4}$ | 1.7 |
| Cadmium | 0.219 | $3.2 \times 10^{-4}$ | 1.0 | $6.4 \times 10^{-3}$ | 2.9 |
| Chromium | 64.0 | $4.7 \times 10^{-4}$ | 5.0 | 0.941 | 1.5 |
| Lead | 14.3 | $<1 \times 10^{-3}$ | 5.0 | $<2 \times 10^{-2}$ | 0.14 |
| Mercury | <0.62 | $<1.2 \times 10^{-2}$ | 0.2 | <0.25 | ? |
| Selenium | 2.78 | $5.9 \times 10^{-2}$ | 1.0 | 1.17 | 42 |
| Thallium | 0.122 | $2.2 \times 10^{-3}$ | NS[c] | $4.5 \times 10^{-2}$ | 37 |

[a] Possible analytical interference.

[b] Federal Register 40 CFR Part 261.24 May 19, 1980.

[c] Not Specified.

With two exceptions, less than three percent of each element was extractable. About 40 percent of the selenium and thallium was extracted.

### 6.4.7 GC-MS Analysis of Baghouse Emissions

The sample extracts of baghouse outlet runs No.1, 3, and 4 were combined for a single GC-MS analysis. The samples were composited as follows. There are three samples for each run (probe wash, filter extract, and XAD-2 resin extract). The original volume of each extract was 10.0 mL. One (1.0) mL of each extract (9.0 mL total), or 10 percent of the extract, was transferred to a single vial. This sample was sent to Stewart Laboratories for analysis. Their results (Appendix A) are reported in nanograms (ng) per microliter (μL). Thus, their results should be multiplied by 90 to get the micrograms (μg) in the total original extracts.

The results of the analysis are given in Table 35. Concentration in the gas was calculated by dividing the total μg by the total gas volume collected for the three runs. The amount emitted was calculated using the average baghouse outlet flow rate for the three runs.

Four of the compounds identified were found in very low concentrations (weak mass spectrograph signal). Thus, concentration for these compounds should be considered as estimates only and may be in considerable error. Of particular concern to us, from the standpoint of comparing the data to BaP concentration determined in the RTI laboratory, is that BaP and BeP were not resolved. The combination of these two facts makes any comparison to the RTI determined BaP concentrations impossible.

Two of the compounds, benzo(a)anthracene and chrysene, are known carcinogens. BaP is also a known carcinogen but BeP is not. Thus, these data are not sufficient to make a definite statement with regards to BaP. The sum of all identified polynuclear aromatics is about 1.5 mg/m$^3$.

## TABLE 35. GC-MS ANALYSIS OF BAGHOUSE EMISSION SAMPLES, SILICON METAL FURNACE

| Component | Total[a] in Samples µg | Concentration in Gas, µg/m$^3$ | Emitted per hour grams |
|---|---|---|---|
| Naphthalene | 7,290 | 957 | 629 |
| Biphenyl | 1,070 | 141 | 92.4 |
| Fluorene | 110 | 14 | 9.3 |
| Anthracene | 1,310 | 172 | 113 |
| Methylanthracenes[b] | 380 | 50 | 33 |
| Phenylnaphthalene | 320 | 41 | 27 |
| Fluoranthene | 500 | 66 | 43 |
| Pyrene | 280 | 37 | 24 |
| Benzo(a)anthracene[b] | 30 | 4 | 2 |
| Chrysene | 80 | 10 | 7 |
| Benzo(a&e)pyrene[c] | 390 | 51 | 33 |
| Perylene (possible)[b] | 170 | 22 | 15 |
| Total: | 11,930 | 1,565 | 1,028 |

[a] All samples from baghouse outlet runs 1, 3, and 4 combined for single analysis.

[b] Quantitation suspect due to low level of compound in sample analyzed.

[c] Unresolved.

## 7.0 TESTING OF OPEN FURNACE PRODUCING HC FeMn

These tests were done on No.3 and 4 furnaces and baghouse at Roane, Ltd.'s plant (SAMANCOR) in Rockwood, TN, February 10, 11, and 12, 1981.

### 7.1 SITE DESCRIPTION

### 7.1.1 General Plant

There are seven open type submerged-arc furnaces, all with design rating between 9 and 11 MW, at the plant. FeMn, SiMn, and FeSi are manufactured at the plant. Furnace fumes are collected above each furnace and ducted to baghouses. Raw materials are stored in partially covered bins keeping most, but not all, rain, snow, etc., off the material. Finished products are stored under cover.

A single baghouse may be used to control the fume from two or more furnaces. Some attempts, none very successful, have been made to recycle the dust to the furnace. Currently, all dust collected by the baghouses is transferred to enclosed trucks and hauled away for disposal.

### 7.1.2 Description: Furnace 3 and 4 and Associated Pollution Capture Equipment

Testing at this plant was for the combined fume from furnaces Nos.3 and 4. These furnaces were both producing H.C. FeMn, are of equivalent size (9-10 MW), and use a common baghouse for emission control (see Figure 5). Both furnaces use three 0.89 meters (35 inches) diameter prebaked electrodes.

Raw materials are fed into the furnaces on an as-needed basis via chutes that extend to the surface of the furnace charge. Raw material consumption is monitored by counting the number of raw material mixes delivered via "trip" car to the furnace storage bins.

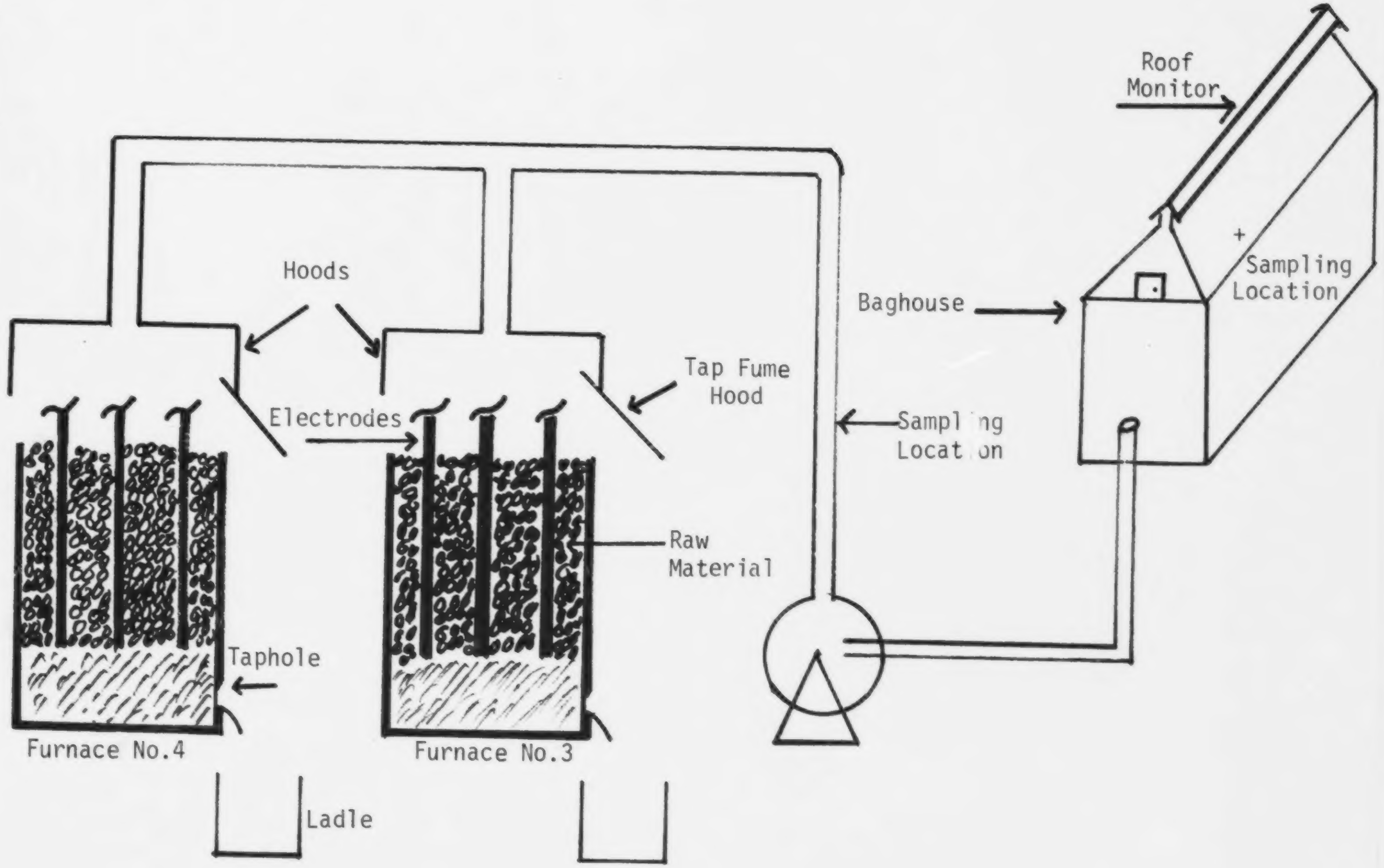
Roof
Monitor
Hoods
Baghouse
Sampling
Location
Tap Fume
Hood
Electrodes
Sampling
Location
Raw
Material
Taphole
Furnace No.4
Furnace No.3
Ladle

Figure 5. Schematic of furnaces No.3 and 4 and associated pollution control equipment.

There is one taphole in each furnace. The furnaces do not rotate. A metal hood extends outward, from the main furnace hood, over the taphole, to direct the tapping fume into the main hood. The tap hood is undersized and does not achieve good fume collection. The taphole is opened with an oxygen lance and jack hammer. The molten alloy and slag flow into ladles below the taphole and are separated. At the end of the tap clay plugs are forced into the taphole to plug it. The molten alloy is poured into molds, referred to as chills, to cool. The chills are lined with FeMn fines from the crushing operation.

Gases produced by furnace reactions mix with ambient air and burn above the furnace. The combusted gas and excess air are drawn into the hood above each furnace. Fumes collected from both furnaces, and a small amount of the tap fume, enter the common ductwork (see Figure 5) leading to the baghouse. The inside diameter of the common duct (where the baghouse inlet tests were done) is 2.72 meters (107 inches). A tempering air damper, located between the inlet sample point and the baghouse, admits ambient air if the stack gas temperature exceeds a preset limit. The damper did not open during the test period. The collected furnace gases are forced into the baghouse by one 1250 horsepower fan designed to handle 7360 $m^3$/min at 260°C (260,000 acfm at 500°F). The baghouse has 12 compartments each with 1230 $m^2$ (13,248 $ft^2$) - total 14,770 $m^2$ (158,976 $ft^2$) of cloth filtration area. The filtered air rises through the compartments and is directed toward the center line of the baghouse where it exhausts through a monitor. Ambient air is also drawn into the baghouse through the open grates at the bottom of each compartment. To clean the bags, one compartment is isolated, the bags deflated and cleaned by reverse air. The compartment is then repressurized and put back on line. Each compartment is cleaned once every 50 minutes. The dust collected is conveyed to a central storage hopper for transfer to an enclosed truck.

## 7.2 PROCESS CONTROL

These furnaces were being used to produce standard high carbon ferromanganese (HC FeMn). This is accomplished by mixing manganese ores with reductants (carbon from coke and electrode) and heating to a sufficiently high temperature to allow the primary reactions:

$$Mn_3O_4 + 4C \rightarrow 3Mn + 4CO$$

$$Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$$

to occur.

Sufficient iron is contained in the manganese ore to satisfy product requirements. Some product (HC FeMn) fines and remelts are recycled to the furnace for recovery. The alloy and slag produced accumulate in the bottom of the vessels. The furnaces are tapped based on power consumption (at about 20 MW-hr intervals).

The furnace operation can be controlled by adjusting the ratio of raw materials (response to this change is slow), and by varying the power input. (Response to this change is relatively rapid). Power input can be varied by either changing the applied voltage or moving the electrodes vertically. Surface stoking is also important to minimize furnace blows.

It is important that alloy and slag be completely removed from the furnace during each tap. Incomplete tapping can result in slag boil- over (slag rises in the area surrounding the electrodes and flows over the surface of the raw material charge).

## 7.3 TEST DESCRIPTION

Figure 5 is a schematic of furnaces Nos.3 and 4 and the related pollution control equipment. Sample point locations are identified in the figure. Figures 6 and 7 give more detail on the inlet sample point location (see Figure 4, Section 6) for typical baghouse outlet sample location.

As shown, the inlet sample ports were located 90° apart in the 2.72 meters (107 inches) diameter duct. The sample ports were located in the lower half of the duct, 45° from the vertical axis. The nearest flow disturbances were: upstream from sample point, 7.85 stack diameters; downstream from sample point, 5.61 stack diameters. Eight points were sampled in each traverse axis (16 points total) for each test.

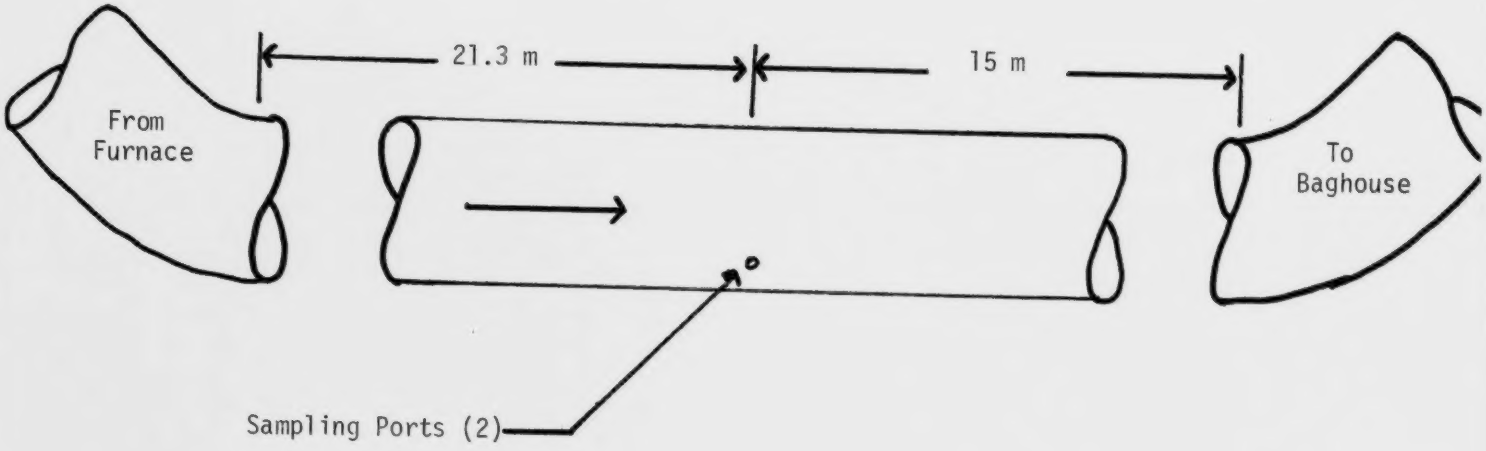
21.3 m
15 m
From Furnace
To Baghouse
Sampling Ports (2)

Figure 6. Baghouse inlet duct dimensions and sampling port locations.

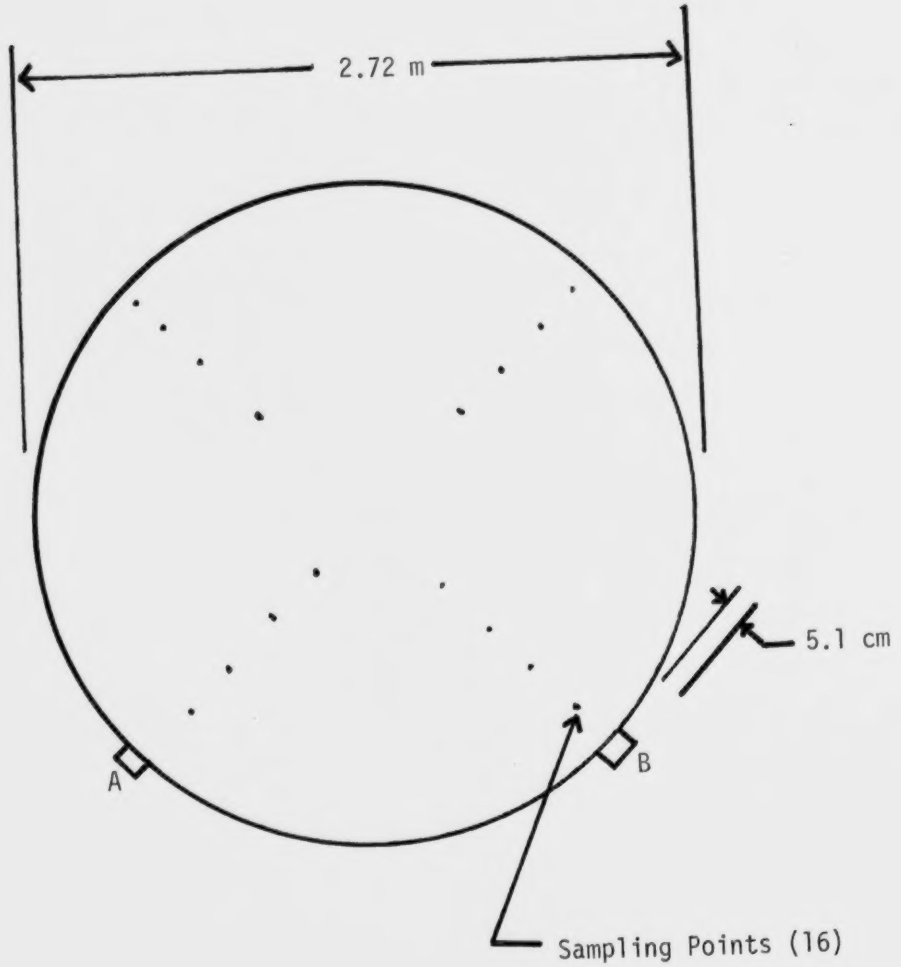
2.72 m
5.1 cm
A
B
Sampling Points (16)

Figure 7. Inlet duct cross-section showing sampling point locations.

Ports for sampling the baghouse outlet were located in the compartment doors in the upper maintenance alleyway. The probe was inserted into the compartment about 2.13 meters (7 feet). Each compartment was sampled at only one point (no traverse). Four of the 12 total compartments were sampled for each test.

Sampling at both locations was done by EPA Methods 1-5, as applicable (see Appendix for details of Methods) with the following exceptions:

1. The sampling train was modified by inserting a cartridge, containing about 100 grams XAD-2 resin, between the third and fourth impingers to capture organic vapors.
2. Baghouse outlet samples were collected at between 0.21 and 0.028 $m^3$/min (0.75 and 1.00 $ft^3$/min) without regard for isokinetics. Sampling at higher than isokinetic rates will have little effect on particulate concentrations determined since the mean aerodynamic diameter of particles escaping the baghouse is quite small.
3. The sample train was cleaned with methylene chloride rather than acetone to insure complete recovery of organics.
4. Methylene chloride was added to the impinger reagents during sample recovery. The impinger reagents were extracted in the laboratory for organic recovery.

Simultaneously with the sampling activity, process operating information was also collected. This included:

1. Raw materials going to the furnace -- from plant records.
2. Furnace power consumption -- instantaneous and cumulative, read from meters in the control room.
3. Slag/alloy ratios, weight of alloy produced, and chemical analyses -- all from plant records.
4. Time and duration of tapping.
5. Furnace operating conditions.

Given in Tables 36 and 37 are the pertinent sampling data for the baghouse inlet and outlet. The outlet gas flow rate from the baghouse was calculated using inlet gas flow rate and temperature, ambient temperature (10°C on 2/10/81, 1.7°C on 2/11/81, and 6.7°C on 2/12/81), and baghouse exhaust gas temperature. Based on these measurements, ambient air drawn in

TABLE 36. BAGHOUSE INLET SAMPLING DATA

| Run No.<br>Date | 1<br>2/10/81 | 2<br>2/11/81 | 3<br>2/11/81 | 4<br>2/11/81 | 5<br>2/12/81 | 6<br>2/12/81 |
|---|---|---|---|---|---|---|
| Start Time | 0947[a] 1355 | 0940 | 1323 | 1605 | 0955 | 1358 |
| Stop Time | 1017 1540 | 1140 | 1503 | 1755 | 1305 | 1600 |
| Net Sampling Time, min | 96 | 96 | 96 | 96 | 96 | 96 |
| Stack Temperature, °C | 84 | 81 | 79 | 74 | 77 | 82 |
| Stack Flow Rate, $dsm^3/min$[b] | 5,894 | 6,182 | 6,202 | 6,283 | 6,208 | 5,982 |
| Stack Flow Rate, A $m^3/min$[c] | 7,502 | 7,830 | 7,797 | 7,775 | 7,545 | 7,389 |
| Volume Collected, $dsm^3$[b] | 0.5955 | 0.6422 | 0.6618 | 0.6711 | 0.6677 | 0.6363 |
| Percent Isokinetic | 87.9 | 90.4 | 92.8 | 92.9 | 93.6 | 92.5 |

[a] Run interrupted by furnace shutdown (10:17 until 11:45).

[b] Moisture free and at 20°C and 76.0 cm Hg.

[c] Actual flow rate at stack conditions.

### TABLE 37. BAGHOUSE OUTLET SAMPLING DATA

| Run No.<br>Date | 1<br>2/10/81 | 2<br>2/11/81 | 3<br>2/11/81 | 4<br>2/12/81 |
|---|---|---|---|---|
| Start Time | 0915[a] 1340 | 0920 | 1308 | 0945 |
| Stop Time | 1017 1610 | 1248 | 1655 | 1325 |
| Net Sampling Time, min | 160 | 160 | 160 | 160 |
| Stack Temperature, °C | 74 | 63 | 57 | 56 |
| Volume Collected, $dsm^3$[b] | 3.3895 | 4.2730 | 3.8681 | 4.1258 |
| Total Gas Flow Rate, $dsm^3/min$[c] | 6,870 | 7,980 | 8,510 | 8,290 |
| Compartments Sampled | 2,3,4,9 | 10,11,12,1 | 5,6,7,8 | 5,6,7,8 |

[a] Run interrupted by furnace shutdown (10:17 until 11:45).

[b] Moisture free and at 20°C and 76.0 cm Hg.

[c] Calculated based on inlet flow rate and temperature, outlet temperature, and ambient air temperature. Ambient air temperatures: 2/10/81 (10°C); 2/11/81 (1.7°C); 2/12/81 (-6.7°C).

through the baghouse grates represented about 14, 23, 27, and 25 percent of the baghouse outlet flow rate for outlet runs 1, 2, 3, 4, respectively.

It is important to note that sampling did not occur continuously from start time until stop time. Sampling was interrupted whenever either furnace was not operating. Generally these furnace outages were of short duration (1-5 minutes). Whenever a more prolonged outage occurred, the furnaces were allowed to stabilize for half the outage time before sampling was resumed. The only extended outage occurred during Run No.1 when a slag boil over occurred on furnace No.4 shortly after testing began. Several outages of 5-50 minutes occurred throughout the test period to repair water leaks and manually slip electrodes.

Given in Table 38 are the raw material consumption figures for the first two shifts of each test day. The first shift data, during which no testing occurred, are important since this indicates any variation in furnace operating practice before and during testing. Although there was some variability in total quantities of raw material charged, the ratio of mix components was essentially constant. Three manganese ores were used. No iron scrap or ore was used since sufficient iron was contained in the manganese ores.

Also contained in the material charged to the furnaces was a small amount of recycled alloy (fines and remelts). Note that none of the results given have been corrected for this recycle, i.e., neither raw material fed nor alloy produced was reduced by the recycle rate. Reductant for the process is supplied completely by buckwheat coke (B.W. coke) and carbon from the electrodes. Weight of electrode consumed is not included in the tables since determining this weight over a short time period (less than several days) is difficult and highly inaccurate. For those wishing to include electrode consumption, plant records indicate an electrode consumption rate of about 7.82 Kg/MW-hr.

Given in Table 39 are the electric power consumption meter readings taken in the furnace control room. Note that the total megawatt hour meter has a constant multiplier of five (5). Thus, to obtain actual megawatt hours consumed in a given time period, the difference in meter readings must be divided by five (5). The instantaneous readings, in actual megawatts, were

TABLE 38a. RAW MATERIAL CONSUMPTION, FURNACE NO.3 (in Kg)

| Date | 2/10/81 | 2/10/81 | 2/11/81 | 2/11/81 | 2/12/81 | 2/12/81 |
|---|---|---|---|---|---|---|
| Shift | 11 pm-7 am | 7 am-3 pm | 11 pm-7 am | 7 am-3 pm | 11 pm-7 am | 7 am-3 pm |
| Mn Ore No.1 | 46,357 | 34,768 | 41,390 | 36,423 | 44,702 | 28,145 |
| Mn Ore No.2 | 12,701 | 9,525 | 11,340 | 9,979 | 12,247 | 7,711 |
| Mn Ore No.3 | 4,445 | 3,334 | 3,969 | 3,493 | 4,286 | 2,699 |
| Standard Fines | 1,270 | 953 | 1,134 | 998 | 1,225 | 771 |
| Standard Remelts | 3,175 | 2,381 | 2,835 | 2,495 | 3,062 | 1,928 |
| Gravel | 1,905 | 1,429 | 1,701 | 1,497 | 1,225 | 839 |
| B.W. Coke | 13,336 | 10,002 | 12,474 | 10,977 | 13,472 | 8,165 |
| Total: | 83,189 | 62,392 | 74,843 | 65,862 | 80,219 | 50,258 |

TABLE 38b. RAW MATERIAL CONSUMPTION, FURNACE NO.4 (in Kg)

| Date | 2/10/81 | 2/10/81 | 2/11/81 | 2/11/81 | 2/12/81 | 2/12/81 |
|---|---|---|---|---|---|---|
| Shift | 11 pm-7 am | 7 am-3 pm | 11 pm-7 am | 7 am-3 pm | 11 pm-7 am | 7 am-3 pm |
| Mn Ore No.1 | 39,735 | 38,079 | 34,768 | 43,046 | 34,768 | 26,490 |
| Mn Ore No 2 | 10,886 | 10,433 | 9,525 | 11,793 | 9,525 | 7,257 |
| Mn Ore No.3 | 3,810 | 3,651 | 3,334 | 4,128 | 3,334 | 2,540 |
| Standard Fines | 1,089 | 1,043 | 953 | 1,179 | 953 | 726 |
| Standard Remelts | 2,722 | 2,608 | 2,381 | 2,948 | 2,381 | 1,841 |
| Gravel | 1,633 | 1,565 | 1,429 | 1,769 | 953 | 726 |
| B.W. Coke | 11,975 | 11,476 | 10,478 | 12,973 | 10,002 | 7,620 |
| Total: | 71,850 | 68,855 | 62,868 | 77,836 | 61,916 | 47,173 |

## TABLE 39. POWER CONSUMPTION RECORD CONTROL ROOM METER READING, MW-hr[a]

| Date | Time | Furnace No.3 |  | Furnace No.4 |  |
|---|---|---|---|---|---|
|  |  | Total | Instantaneous | Total | Instantaneous |
| 2/9/81 | 2300 | 27,045.0 |  | 83,412.4 |  |
| 2/10/81 | 700 | 27,457.9 |  | 83,777.2 |  |
|  | 813 | 27,511.0 | 10.3 | 83,832.4 | 10.4 |
|  | 907 | 27,561.3 | 10.3 | 83,869.3 | 9.2 |
|  | 922 | 27,574.0 | 10.4 | 83,882.0 | 10.0 |
|  | 946 | 27,575.4 | 10.4 | 83,902.9 | 10.2 |
|  | 951-955 |  |  | Shutdown |  |
|  | 1001 | 27,608.3 | 10.4 | 83,912.7 | 9.2 |
|  | 1005 |  |  |  | 9.0 |
|  | 1014 |  |  |  | 9.6 |
|  | 1017 | Shutdown |  | Shutdown |  |
|  | 1145 | Both furnaces operating |  |  |  |
|  | 1400 | 27,762.3 | 10.4 | 84,057.4 | 8.5 |
|  | 1414 | 27,776.3 | 10.4 | 84,069.6 | 9.0 |
|  | 1426 |  |  | Shutdown |  |
|  | 1430 | 27,788.2 | 10.3 | 84,076.8 | 0.0 |
|  | 1431 | Shutdown |  |  |  |
|  | 1444 |  |  | Operating |  |
|  | 1447 | Operating |  |  |  |
|  | 1500 | 27,811.2 | 10.4 | 84,089.0 | 9.2 |
|  | 1532 | 27,839.2 | 10.4 | 84,113.4 | 9.0 |
|  | 1545 |  | 10.3 |  | 9.3 |
|  | 1601 | 27,865.3 | 10.3 | 84,136.4 | 9.0 |
|  | 1630 | 27,891.0 | 10.2 | 84,157.9 | 8.2 |
| 2/11/81 | 700 | 28,568.4 |  | 84,803.4 |  |
|  | 746-902 |  |  | Shutdown |  |
|  | 830-838 | Shutdown |  |  |  |
|  | 915 | 28,688.6 | 10.4 | 84,853.5 | 9.7 |
|  | 952 | 28,718.6 | 10.4 | 84,881.9 | 10.2 |
|  | 1031-1055 | Shutdown |  |  |  |
|  | 1042 |  |  | 84,923.8 | 9.6 |
|  | 1115 | 28,767.9 | 10.3 | 84,950.4 | 9.6 |
|  | 1157 | 28,804.8 | 10.2 | 84,985.9 | 10.5 |
|  | 1230 | 28,834.6 | 10.3 | 85,010.0 | 10.2 |
|  | 1305 | 28,862.6 | 10.4 | 85,036.6 | 10.0 |
|  | 1328 | Shutdown for 2 minutes |  |  |  |
|  | 1330 | 28,880.4 | 0 | 85,053.4 | 9.5 |
|  | 1400 | 28,907.6 | 10.4 | 85,078.5 | 8.5 |
|  | 1430 | 28,932.4 | 10.8 | 85,101.6 | 9.6 |
|  | 1457 | Shutdown for 2 minutes |  |  |  |

continued

TABLE 39 (continued).

| Date | Time | Furnace No.3 Total | Furnace No.3 Instantaneous | Furnace No.4 Total | Furnace No.4 Instantaneous |
|---|---|---|---|---|---|
| 2/11/81 (cont'd) | 1502 | 28,957.0 | 10.2 | 85,126.0 | 9.8 |
| | 1504 | Shutdown | | | |
| | 1537 | | | 85,154.6 | 9.9 |
| | 1551 | Operating | | | |
| | 1557-1559 | | | Shutdown | |
| | 1600 | 28,967.3 | 10.5 | 85,171.8 | 10.0 |
| | 1630 | 28,992.9 | 10.4 | 85,196.1 | 10.1 |
| | 1657-1700 | Shutdown | | Shutdown | |
| | 1702 | 29,018.1 | 10.5 | 85,219.3 | 10.5 |
| | 1730 | 29,043.6 | 10.6 | 85,244.0 | 10.6 |
| | 1758-1800 | | | Shutdown | |
| | 1815 | 29,081.7 | 10.2 | 85,278.8 | 9.8 |
| | 1830 | 29,071.8 | 10.6 | 85,269.3 | 9.9 |
| 2/12/81 | 700 | 29,735.2 | | 85,859.6 | |
| | 937 | 29,865.8 | 10.4 | 85,993.2 | 10.5 |
| | 1000 | 29,885.6 | 10.4 | 86,011.9 | 10.5 |
| | 1010-1013 | | | Shutdown | |
| | 1017-1022 | | | Shutdown | |
| | 1030 | 29,912.3 | 10.4 | 86,030.6 | 10.0 |
| | 1037 | | | Shutdown | |
| | 1100 | 29,939.1 | 10.4 | 86,035.6 | 0 |
| | 1105 | | | Operating | |
| | 1113-1115 | Shutdown | | | |
| | 1130 | 29,962.4 | 10.5 | 86,056.6 | 9.8 |
| | 1200 | 29,987.0 | 10.5 | 86,081.1 | 10.1 |
| | 1232 | 30,014.2 | 10.4 | 86,108.3 | 9.7 |
| | 1300 | 30,038.1 | 10.1 | 86,129.9 | 9.9 |
| | 1330 | 30,063.9 | 10.4 | 86,154.2 | 10.0 |
| | 1401 | 30,088.7 | 10.3 | 86,179.5 | 9.7 |
| | 1430 | 30,114.4 | 10.3 | 86,203.6 | 10.0 |
| | 1500 | 30,139.6 | 10.2 | 86,226.7 | 9.6 |
| | 1510-1522 | | | Shutdown | |
| | 1532 | 30,167.7 | 10.2 | 86,241.7 | 10.2 |
| | 1600 | 30,192.4 | 10.5 | 86,265.8 | 10.4 |
| | 1630 | 30,218.3 | 9.9 | 86,290.1 | 9.7 |
| | 1700 | 30,244.4 | 10.4 | 86,314.5 | 9.5 |
| | 1715 | 30,258.0 | 10.4 | 86,327.1 | 9.6 |

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[a] Actual furnace meter readings are given under columns headed "Total." To obtain actual MW-hrs consumed, divided the difference between meter readings by five (5). Columns headed "Instantaneous" give actual furnace operating MW load at that time.

Special Note: testing occurred only when both furnace were operating.

taken from the chart recorder in the control room and indicate the rate of power consumption at that instant only. Also noted in this table are periods of furnace outages. Testing did not occur when either furnace was not operating.

Given in Table 40 are data pertaining to furnace tapping. In Section A of the table are the times at which the taphole was opened during the testing periods. Each furnace was generally tapped 9 or 10 times per day (24 hours) at about 20 MW-hr intervals. Tapping generally took 15-20 minutes. Tapping should, however, have little effect on the particulate data obtained because tap fumes were normally quite light and tap fume collection was estimated to be usually less than 50 percent.

Section B of the table gives the total alloy tapped (does not include slag), for each 24-hour day. Individual tap weights were obtained but could not be used with confidence because the small amount of slag remaining with some taps was reported only on a daily basis. The daily tap weights given by the plant were also reduced by five percent as recommended by plant personnel to correct for incorporation of fines which are used to line the chills. Also given in the table are the average daily weights of alloy (corrected as above) produced per MW-hr (total daily power consumption from plant records).

Given in Table 41 are the daily average alloy and slag analyses for the two furnaces. There is little variability in the analyses which indicates production of a uniform product during the test period.

## 7.4 TEST RESULTS

### 7.4.1 Gas Analysis

During Run No.1 at the baghouse inlet and Run No.3 at the baghouse outlet, gas samples were collected and Orsat gas analysis performed. The gas analyses were identical. The results are given in Table 42.

These data suggest that fairly complete combustion of the furnace gas is occurring. As noted previously, the reaction gases burn above the surface of the raw material charged into the furnace. They also show that a large volume of ambient air, relative to the volume of gas produced by the furnace, is drawn into the furnace fume collection system. The ORSAT gas analysis is almost the same as ambient air.

## TABLE 40. TAPPING DATA

A. Tap Occurring During Testing

| Date | Tap Time, Furnace 3 | Tap Time, Furnace 4 |
|---|---|---|
| 2/10/81 | 1410 | 1342 |
| | 1622 | 1618 |
| 2/11/81 | 1010 | 1106 |
| | 1240 | 1325 |
| | 1447 | 1536 |
| | 1745 | 1748 |
| 2/12/81 | 1045 | 954 |
| | 1255 | 1230 |
| | 1508 | 1440 |

B. Product Tapped[a]

| Date | Kg Product Furnace 3 | Kg Product[b] per MW-hr | Kg Product Furnace 4 | Kg Product[b] per MW-hr |
|---|---|---|---|---|
| 2/10/81 | 76,093 | 341.5 | 81,152 | 406.7 |
| 2/11/81 | 80,339 | 348.7 | 66,386 | 303.1 |
| 2/12/81 | 78,926 | 332.6 | 67,774 | 315.9 |

---

[a] As tapped, not saleable product, and corrected for fines pick up in chills. These data are on a 24 hour day basis. Accurate individual tap weights could not be obtained.

[b] Corrected for fines pick up in chills but not for recycled fines and remelts.

## TABLE 41. PRODUCT AND SLAG ANALYSIS, IN PERCENT

| Component | Furnace 3 2/10/81 | Furnace 4 2/10/81 | Furnace 3 2/11/81 | Furnace 4 2/11/81 | Furnace 3 2/12/81 | Furnace 4 2/12/81 |
|---|---|---|---|---|---|---|
| Alloy | | | | | | |
| Mn | 78.40 | 78.00 | 78.53 | 77.67 | 78.07 | 78.20 |
| Fe | 12.86 | 13.38 | 12.79 | 13.66 | 13.15 | 13.09 |
| Si | 0.37 | 0.13 | 0.25 | 0.24 | 0.46 | 0.32 |
| C | 6.87 | 6.99 | 6.93 | 6.93 | 6.82 | 6.89 |
| Total: | 98.5 | 98.5 | 98.5 | 98.5 | 98.5 | 98.5 |
| Slag | | | | | | |
| Mn[a] | 18.80 | 23.27 | 17.33 | 20.97 | 19.17 | 18.77 |
| MnO | 24.25 | 30.02 | 22.36 | 27.05 | 24.73 | 24.21 |
| FeO | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| $SiO_2$ | 33.67 | 29.04 | 32.64 | 30.91 | 32.59 | 31.81 |
| $Al_2O_3$ | 2.16 | 2.67 | 2.19 | 1.59 | 3.12 | 2.65 |
| CaO | 30.14 | 28.60 | 32.53 | 30.56 | 29.58 | 30.84 |
| MgO | 7.06 | 6.96 | 7.56 | 7.16 | 7.26 | 7.76 |
| BaO | 0.82 | 0.81 | 0.82 | 0.83 | 0.82 | 0.83 |
| Total: | 98.45 | 98.45 | 98.45 | 98.45 | 98.45 | 98.45 |
| Slag/alloy ratio | 1.00 | 0.90 | 0.83 | 0.95 | 0.77 | 0.78 |

[a] Both Mn and MnO percentages are given for slag analysis. Only the percent MnO should be included in the total.

TABLE 42. ORSAT GAS ANALYSIS, BAGHOUSE INLET AND OUTLET

| Component | Percent, by Volume[+] |
|---|---|
| $N_2$ | 79.1 |
| $O_2$ | 19.8 |
| $CO_2$ | 1.1 |
| CO | 0.0 |

+Dry basis.

### 7.4.2 Particulates

Given in Table 43 are the results obtained for particulate matter in the baghouse inlet gas. Particulate concentrations in the gas averaged about 250 mg/dsm$^3$ with a range of approximately 160-360 mg/dsm$^3$. Total particulate generated by the furnace averaged about 93 Kg/operating hour, with a range of approximately 60-130 Kg/hour. In terms of operating parameters, the average amount of particulate generated was about 4.7, 5.6, and 14 Kg per MW-hr, per Mg raw material fed, and per Mg alloy tapped, respectively.

The variability in fume generation rate does not seem to correlate with the operating parameters of average load, rate of raw material feed, or rate of alloy production. Tapping is also unlikely to be the cause of this variability since tap fume collection was generally less than 50 percent and tap fumes were light. Light blows and furnace stoking, which occurred occasionally during all runs, are the most likely explanations for the observed variability in fume generation. Even these, however, do not seem to be strongly correlated.

Since no unusual conditions existed during the six tests made, the overall averages should represent a fairly good approximation of the average particulate generation rate for the furnaces during the test period.

Given in Table 44 are the particulate results obtained for the baghouse exhaust. The average particulate concentration in the gas emitted was about

TABLE 43. PARTICULATES, BAGHOUSE INLET

| Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Generated[a] per hour, Kg | Average Load[b] During Test MW-hr/hr | Generated per MW-hr Kg | Generated[c] per Mg Feed Kg | Generated[d] per Mg Alloy Kg |
|---|---|---|---|---|---|---|---|
| 1 | 222.5 | 373.6 | 132.1 | 19.9 | 6.64 | 6.73 | 17.9 |
| 2 | 166.4 | 259.1 | 96.1 | 19.9 | 4.83 | 4.69 | 14.8 |
| 3 | 124.7 | 188.4 | 70.1 | 19.2 | 3.65 | 3.57 | 11.2 |
| 4 | 109.8 | 163.6 | 61.7 | 20.5 | 3.01 | 2.94 | 9.2 |
| 5 | 223.5 | 334.7 | 124.7 | 20.1 | 6.20 | 9.82 | 19.1 |
| 6 | 149.2 | 234.5 | 84.2 | 20.1 | 4.19 | 6.62 | 12.9 |
| Average, all runs | | 253.2 | 94.8 | | 4.75 | 5.73 | 14.2 |

[a] Per operating hour.

[b] Total, both furnaces.

[c] Total Mg fed on shift divided by total MW-hr on shift to get Mg fed/MW-hr (for each furnace). These numbers multiplied by average load during test for each furnace to get Mg fed per operating test hour. Data summed for both furnaces and divided into Kg particulate generated per operating hour.

[d] Megagram (Mg) alloy produced per MW-hr (average for entire day) calculated from plant record (see Table 40) for each furnace. These data multiplied by average load (each furnace) during test to get Mg alloy produced per operating test hour. This data summed for both furnaces and divided into Kg particulate generated per operating hour.

TABLE 44 . PARTICULATES, BAGHOUSE OUTLET[a]

| Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Emitted per hour Kg | Average Load During Test | Emitted per MW-hr Kg | Emitted per Mg Feed Kg | Emitted per Mg Alloy Kg |
|---|---|---|---|---|---|---|---|
| 1 | 5.0 | 1.48 | 0.61 | 19.9 | 0.031 | 0.031 | 0.082 |
| 2 | 29.8 | 6.97 | 3.34 | 19.8 | 0.169 | 0.164 | 0.517 |
| 3 | 7.0 | 1.81 | 0.93 | 19.7 | 0.047 | 0.046 | 0.144 |
| 4 | 10.8 | 2.62 | 1.30 | 20.1 | 0.065 | 0.103 | 0.200 |
| Average, all tests |  | 3.22 | 1.54 |  | 0.078 | 0.085 | 0.236 |

[a] See notes Table 43 for calculation method.

3.3 mg/dsm$^3$ with an approximate range of 1.5-7.0 mg/dsm$^3$. The average amount of particulate matter emitted was 1.64 Kg/hour, with a range of 0.61-3.34 Kg/hr. In terms of operating parameters, particulate emitted averaged 0.083 Kg/MW-hr, 0.091 Kg/Mg raw material fed, and 0.25 Kg/Mg alloy produced (tap weight).

Two of the four runs (3 and 4) were made in the same four compartments on different days. Particulate emission rates and baghouse collection efficiency (see Table 45) were virtually identical for these two tests. Runs 1 and 2 were made in different sets of compartments (and different from those in tests 3 and 4). Since no unusual occurrences were noted during any of the tests, it can be assumed that the data represent actual differences in the performance of the compartments tested. Thus, the four run average for the baghouse inlet should represent a fairly good approximation of the actual amount of particulate emitted from the baghouse during the test period.

Based on the test data, about 2190 Kg (2.4 tons) of particulate are captured by the baghouse for a 24 hour operating period.

Given in Table 45 are the calculated baghouse particulate capture efficiencies. The overall capture efficiency was over 98 percent with a range of 96.4 to 99.5 percent. There was no evidence of bag failure during any of the tests.

Federal New Source Performance Standards (NSPS), which do not apply to the furnaces tested, limit emissions from furnaces producing ferromanganese to 0.23 Kg/MW-hr. None of the tests indicated particulate matter emissions in excess of this standard. If more complete capture of tap fume were practiced, complete compliance with NSPS would be achieved. The average amount of particulate matter emitted was about 36 percent of that allowable by NSPS.

### 7.4.3 Organics

Given in Table 46 are the results obtained for organics in the baghouse inlet gas. The concentration in the gas averaged 98 mg/dsm$^3$ for the six runs, with a range of zero to about 190 mg/dsm$^3$. Essentially no organic matter was found in two of the six runs. The furnaces generated an average of 36 Kg organic per operating hour. In terms of operating

TABLE 45. BAGHOUSE PARTICULATE CAPTURE EFFICIENCY

| Outlet Run Number | Inlet Run Number Used In Calculation | Baghouse[a] Particulate Capture Efficiency |
|---|---|---|
| 1 | 1 | 99.5 |
| 2 | 2 | 96.5 |
| 3 | 3,4[b] | 98.6 |
| 4 | 5 | 99.0 |
| Average, all runs | | 98.4 |

[a] Calculated using Kg generated and Kg emitted per hour. Comparisons based on particulate concentrations in the gases will overstate baghouse efficiency because of additional air drawn into baghouse through the cooling air grates.

[b] A simple average of the particulate generation rate in inlet Runs 3 and 4 was used. Outlet Run 3 overlapped both inlet Runs 3 and 4.

parameters, the rates for organic matter generation are 1.8 Kg/MW-hr, 2.3 Kg/Mg raw material fed, and 5.3 Kg/Mg alloy tapped.

The organic results do not seem to correlate particularly well with any of the measured or observed process parameters. Excluding the results for runs 3 and 4, which gave zero organic generated, the results fall within a fairly narrow range. We are not aware of any process operations or sampling problems occurring during the test that would explain the results obtained in runs 3 and 4. The possibility does exist that errors could have been made in the transport and/or analysis of these samples. However, since we have no proof of this, and since the results could be caused by some unknown process variation, we have elected to treat these as valid results. We believe, however, these data are suspect.

Based on the six run average, the furnaces were generating about 38 percent as much organic as particulate matter. All of the organic matter was found in the XAD-2 resin, except for the 1 mg found on the particulate of run No.3.

TABLE 46. ORGANICS, BAGHOUSE INLET AND OUTLET

| Location | Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Generated Kg/hr | Generated Kg/MW-hr | Generated Kg/Mg Feed | Generated Kg/Mg Alloy |
|---|---|---|---|---|---|---|---|
| Inlet | 1 | 86 | 144.4 | 51.1 | 2.57 | 2.60 | 6.91 |
| | 2 | 90 | 140.1 | 52.0 | 2.61 | 2.54 | 8.01 |
| | 3 | 1 | 1.51 | 0.56 | 0.029 | 0.029 | 0.089 |
| | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 5 | 76 | 113.8 | 42.4 | 2.11 | 3.34 | 6.51 |
| | 6 | 120 | 188.6 | 67.7 | 3.37 | 5.32 | 10.4 |
| Average, all runs | | | 98.1 | 35.6 | 1.78 | 2.30 | 5.32 |
| | | | | Emitted Kg/hr | Emitted Kg/MW-hr | Emitted Kg/Mg Feed | Emitted Kg/Mg Alloy |
| Outlet | 1 | 123 | 36.29 | 14.96 | 0.75 | 0.76 | 2.01 |
| | 2 | 88 | 20.59 | 9.86 | 0.50 | 0.49 | 1.52 |
| | 3 | 99 | 25.59 | 13.1 | 0.66 | 0.65 | 2.04 |
| | 4 | Lost | | | | | |
| Average runs, 1, 2, 3 | | | 27.5 | 12.6 | 0.64 | 0.63 | 1.86 |

Also given in Table 46 are the organic results for the baghouse outlet. Data were obtained for three of the four runs; one sample from run No.4 was lost during analysis. The average concentration in the outlet gas was about 28 mg/dsm$^3$. The average amount emitted was about 13 Kg/operating hour. In terms of operating parameters, organic emissions were 0.6 Kg/MW-hr, 0.6 Kg/Mg raw material fed, and 1.9 Kg/Mg alloy tapped. All of the organic matter was found in the XAD-2 resin. The baghouse inlet gas temperature was between 74° and 84°C and the baghouse outlet gas temperature was between 57° and 74°C. The sampling train filter box was operated at 121°C as specified by EPA Method 5. It is likely, therefore, that any lower boiling point organics adsorbed on the particulate would have been distilled into the XAD-2 resin. The data would suggest, therefore, that the majority, if not all, of the organic is relatively low boiling point material.

The concentration of organics in baghouse outlet run No.3 (corresponding to inlet runs No.3 and 4) was about 26 mg/dsm$^3$. We do not understand, nor can we offer a good explanation, how this high a concentration could have been measured while no organic was detected in the baghouse inlet gas. Some possibilities are:

1. Analyses for both inlet runs 3 and 4 are in error. This is unlikely since similar, serious errors would have had to be made in two (unrelated as far as the analyst knew) samples.
2. Results for outlet run No.3 are in error. This seems unlikely since the results are so near the average of runs 1 and 2. (The analyst had no way of knowing what results to expect since he did not know the volume of gas sampled.)
3. Inlet sampling did not occur during the first 15 minutes of outlet sampling and for 62 minutes in the middle of outlet sampling. Inlet sampling was occurring for one hour after termination of outlet sampling. The results could be attributable to very high rates of organic generation during periods when inlet sampling was not occurring. This seems unlikely since inlet sample taken before and after the 62 minute nonsampling period contained essentially no organic matter.
4. Ambient air drawn into baghouse grate contained significant amounts of organic. This seems unlikely, considering the concentrations required, locations of the plant, and the fact that the outlet organic concentration did not go down when zero inlet concentration was measured.
5. Organic matter in the baghouse inlet is adsorbed on baghouse filter bags, dust trapped in the bags, and on the dust on the baghouse

walls and is subsequently stripped out by incoming gas (i.e., much like a gc column). This seems the most likely explanation (although certainly not very satisfying), especially since we note that similar phenomena (more organic in outlet than inlet) occurred in all three open furnace baghouse tests.

Accepting all these results as valid, the baghouse organic capture efficiency (see Table 47) was 49 percent.

Using data from outlet runs No.1, 2, and 3 only, it can be seen that organic emissions were considerably greater than particulate emissions (12.6 versus 1.63 Kg/hour). Increasing the particulate collection efficiency of the baghouse would have little effect on organic emissions.

TABLE 47. BAGHOUSE ORGANIC CAPTURE EFFICIENCY

| Outlet Run Number | Inlet Run Number | Efficiency, % |
|---|---|---|
| 1 | 1 | 70.7 |
| 2 | 2 | 81 |
| 3 | 3, 4 | Negative |
| Average, all runs | | 49 |

### 7.4.4 Benzo(a)Pyrene

Given in Table 48 are the results obtained for BaP in the baghouse inlet and outlet samples. BaP was not detected in any of the samples. The average detection limit for inlet samples was 0.8 μg/dsm$^3$ and 0.13 μg/dsm$^3$ for outlet samples.

### 7.4.5 BaP in Baghouse Collected Particulate

A sample of the particulate matter actually collected by the baghouse was collected and analyzed for BaP content. The dust contained 0.84 μg BaP/g.

## TABLE 48. BaP, BAGHOUSE INLET AND OUTLET

| Location | Run Number | μg BaP Captured[a] |
|---|---|---|
| Inlet | 1 | ND[b] |
| | 2 | ? |
| | 3 | ND |
| | 4 | ND |
| | 5 | ND |
| | 6 | ND |
| Outlet | 1 | ND |
| | 2 | ND |
| | 3 | ND |
| | 4 | ND |

[a] Detection limit 0.8 μg/dsm$^3$ for inlet samples and 0.13 μg/dsm$^3$ for outlet samples.

[b] ND = None detected.

[c] Extract of XAD resin lost in analysis.

### 7.4.6 Leaching Test, Baghouse Dust

The baghouse dust was analyzed by AAS for nine metals on EPA's Priority Pollutant list. All of the elements, except antimony, are present (see Table 49) in concentrations that could be of concern.

The dust was then subjected to leaching following procedures given in the Federal Register 40 CFR Part 261, Appendix II, May 19, 1980. The leachate analysis is given in column 3 of the table. None of the metals equal or exceed the permissible concentration given in 40 CFR Part 261.24. Thus, on this basis the solid is nonhazardous.

Given in the last columns of the table are the actual amount of each element extracted and the percentage of the element extracted. In general, less than about 4 percent of the elements is extracted. Notable exceptions are antimony (38 percent) and selenium (84 percent).

TABLE 49. LEACHING TESTS, OPEN H. C. FeMn FURNACE BAGHOUSE DUST

| Element | Concentration in Original Sample, µg/g Solids | Concentration in Leachate mg/L | Amount Leached µg/g Solids | % of Element |
|---|---|---|---|---|
| Antimony | 2.58 | $4.95 \times 10^{-2}$ | 0.99 | 38 |
| Arsenic[a] | 217 | 0.411 | 8.22 | 3.8 |
| Beryllium | 1.40 | $6.1 \times 10^{-3}$ | $3.26 \times 10^{-2}$ | 2.3 |
| Cadmium | 21.4 | $1.14 \times 10^{-3}$ | $2.29 \times 10^{-2}$ | 0.1 |
| Chromium | 146 | 0.309 | 6.17 | 4.2 |
| Lead | 2180 | $2.76 \times 10^{-3}$ | $5.5 \times 10^{-2}$ | $2.5 \times 10^{-3}$ |
| Mercury | <0.62 | $<1.2 \times 10^{-2}$ | <0.25 | ? |
| Selenium | 11.0 | 0.463 | 9.28 | 84 |
| Thallium | 15.4 | $6.9 \times 10^{-3}$ | 0.139 | 0.9 |

[a] Possible analytical interference.

## 8.0 TESTING OF OPEN FURNACE PRODUCING 50 PERCENT FESi

These tests were done on furnace No.2 and associated baghouse at Foote Mineral Company's plant in Graham, WV on March 17 and 18, 1981.

### 8.1 SITE DESCRIPTION

### 8.1.1 General Plant

There are three furnaces at the plant. Furnace design ratings range from 20 to 35 MW. The primary products are various grades of ferrosilicon. Proprietary alloys are also made. All of the furnaces are of the open-type design. Fumes generated by the furnaces are collected and ducted to individual baghouses. Raw materials are stocked outside in uncovered areas.

Dust collected by the baghouses is transferred to a central storage hopper from which it is removed, as necessary, and either left dry or pelletized and then removed by truck for disposal.

### 8.1.2 Description of Furnace No.2 and Associated Pollution Capture Equipment

Testing at this plant was done on furnace No.2 and the baghouse serving this furnace. The furnace was producing standard 50 percent ferrosilicon. The furnace design rating is 35 MW. Three Soderberg electrodes, 1.57 meters (62 inches) in diameter, are used for power input.

Raw materials are fed into the furnace, on an as-needed basis, through chutes which pass through the main hood. The furnace operator controls the time, amount, and location of raw material addition. Total raw material delivered on each shift is monitored by counting the number of raw material mixes delivered via "trip car" to the furnace storage bins.

There is one taphole in the furnace. The furnace does not rotate. A tapping hood surrounds the taphole. The tapping hood has an opening in the bottom to allow the metal to drain into the ladle and a small opening in the front to allow access to the taphole. A tapping hood fan, with a capacity of about 1780 $m^3$/min (63,000 $ft^3$/min), provides the hood draft, forcing tap fumes into the furnace main hood ductwork. The tap fume capture system performed superbly with consistent 100 percent fume collection. The taphole is usually opened with a steel bar, although it may also be oxygen lanced or shot if needed. The molten alloy is tapped into a ladle, transported to the casting area, and poured into chills. After cooling, the solidified alloy is crushed to the size required.

Gases produced by the furnace reactions mix with ambient air above the furnace vessel and burn. The combusted gas is drawn into the hood above the furnace (see Figure 8). All gases from the furnace and the tapping hood enter the main duct leading to the baghouse. The inside diameter of this duct, at the inlet test port location, is 3.81 meters (150 inches). After passing the inlet sample point location, the gases pass through a dust precollector-multiclone for removal of larger sized particles and a series of "U"-shaped radiant cooling tubes. Gases are forced into the baghouse with two 1500 horsepower fans. The system is designed to handle 12,750 $m^3$ of gas at 288°C (450,000 acfm at 550°F).

The baghouse has 11 compartments, each with about 2260 $m^2$ (24,350 $ft^2$)--total 24,880 $m^2$ (267,860 $ft^2$)--of cloth filtration area. The 11 compartments are in-line (other baghouses tested in this study had 12 or 14 compartments, 6 or 7 on each side of the baghouse). Ambient air, for additional bag cooling, is drawn into the baghouses through grates in the bottom of each compartment. Each baghouse compartment is cleaned by reverse air about once each 40 minutes using a 300 horsepower fan. An additional 150 horsepower is used at the baghouse for auxiliary functions such as dust transfer.

## 8.2 PROCESS CONTROL

The furnace was producing 50 percent ferrosilicon. This is accomplished by mixing a silicon source (gravel, primarily) with an iron source (scrap iron) and a reductant (carbon, from coal, woodchips, and electrodes) and heating to a sufficiently high temperature to allow the primary reactions

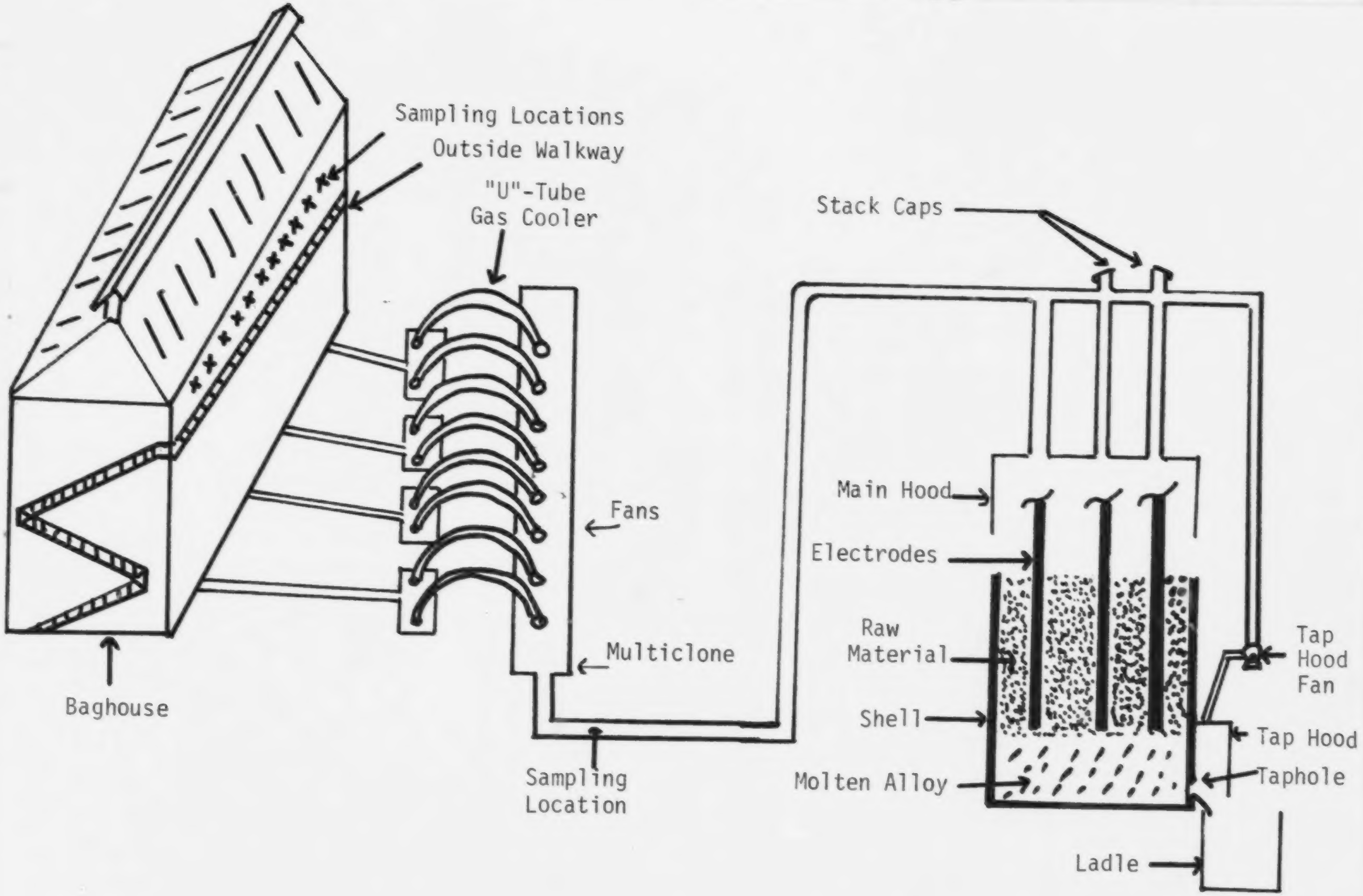
Sampling Locations
Outside Walkway
"U"-Tube
Gas Cooler
Stack Caps
Main Hood
Fans
Electrodes
Raw
Material
Tap
Hood
Fan
Multiclone
Baghouse
Shell
Tap Hood
Sampling
Location
Molten Alloy
Taphole
Ladle

Figure 8. Schematic of furnace No.2 and associated pollution control equipment.

$$SiO_2 + 2C \rightarrow Si + 2CO$$

melts

$$Fe \rightarrow Fe\ (liquid)$$

$$Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$$

to occur.

Woodchips, although providing some reductant carbon, are added primarily to give porosity to the charge. Some silicon remelts are recycled to the furnace for recovery. The molten alloy accumulates in the bottom of the furnace and is tapped out at about 1 to 1.25 hour intervals.

The furnace operation is controlled by adjusting the ratio of raw materials and varying the power input. Power input is adjusted by either changing the applied voltage or moving the electrodes vertically. The furnace operators add raw material and stoke the furnace, as needed, to minimize furnace "blows."

## 8.3 TEST DESCRIPTION

Figure 8 is a schematic of furnace No.2 and the related pollution control equipment. Sample point locations are identified in the figure. Figures 9, 10, and 11 give more detail on the sample point locations.

As shown, the inlet sample ports were located 90 degrees apart in the 3.81 meter (150 inch) diameter duct. The sample ports were located in the upper half of the duct, 45 degrees from the vertical axis. The nearest flow disturbances were: upstream from sample point, 4.44 stack diameters; downstream from sample point, 1.08 stack diameters. Eighteen points were sampled in each traverse axis (36 points total) for each test.

Ports for sampling the baghouse outlet were located in the baghouse compartment walls above the bags. The probe was inserted into the compartment about 1.5 meters (5 feet). Each compartment was sampled at only one point (no traverse). Four of the 11 compartments were sampled for each test. A different set of four compartments was sampled for each test.

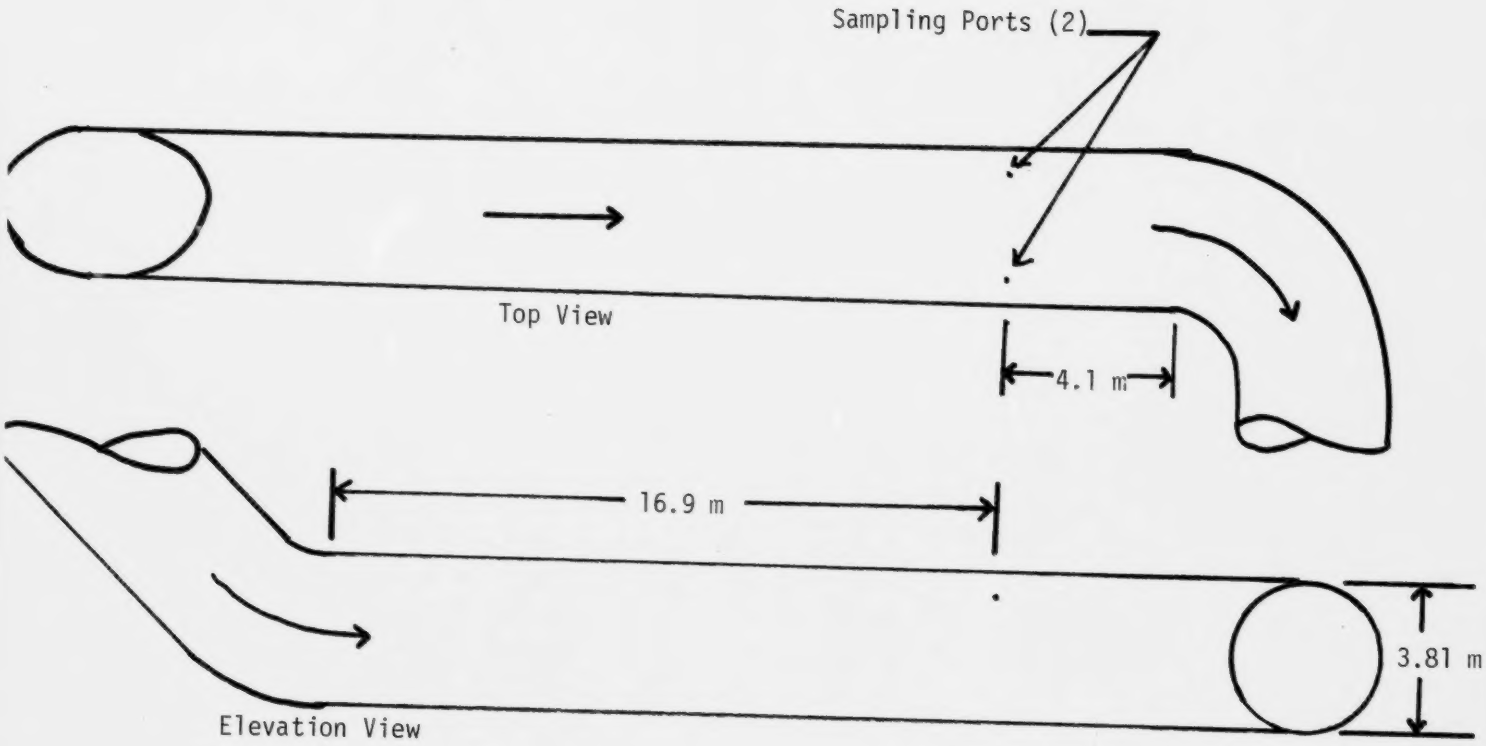
Sampling Ports (2)
Top View
4.1 m
16.9 m
3.81 m
Elevation View

Figure 9. Baghouse inlet duct dimensions and sampling port locations.

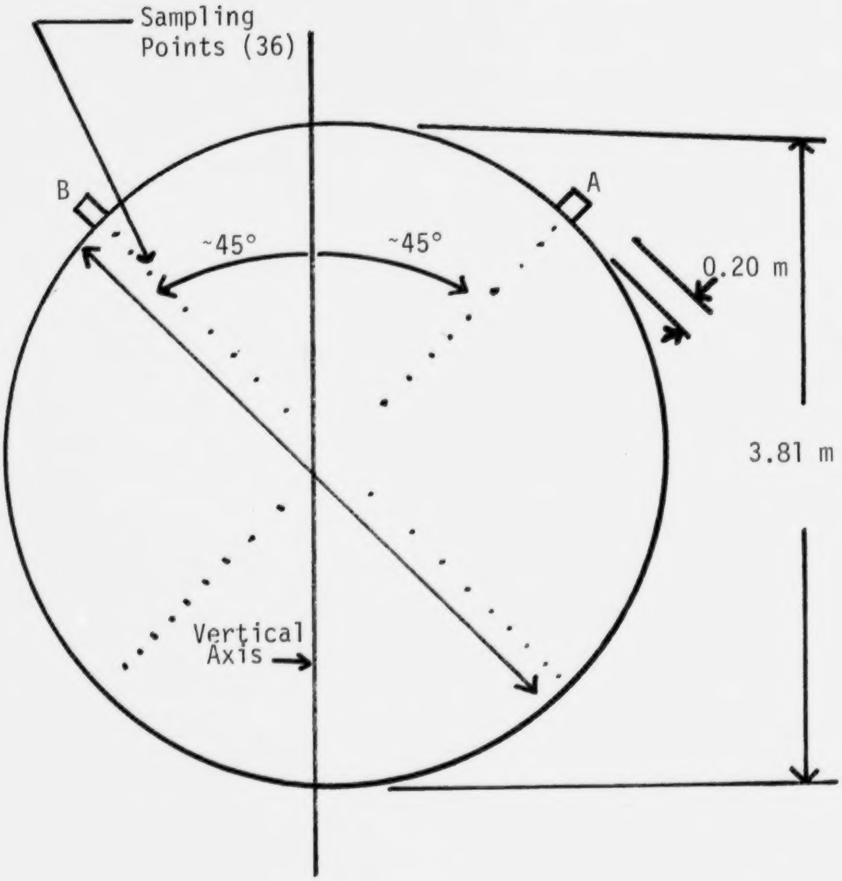
Sampling
Points (36)
B
A
~45°
~45°
0.20 m
3.81 m
Vertical
Axis

Figure 10. Baghouse inlet duct cross-section.

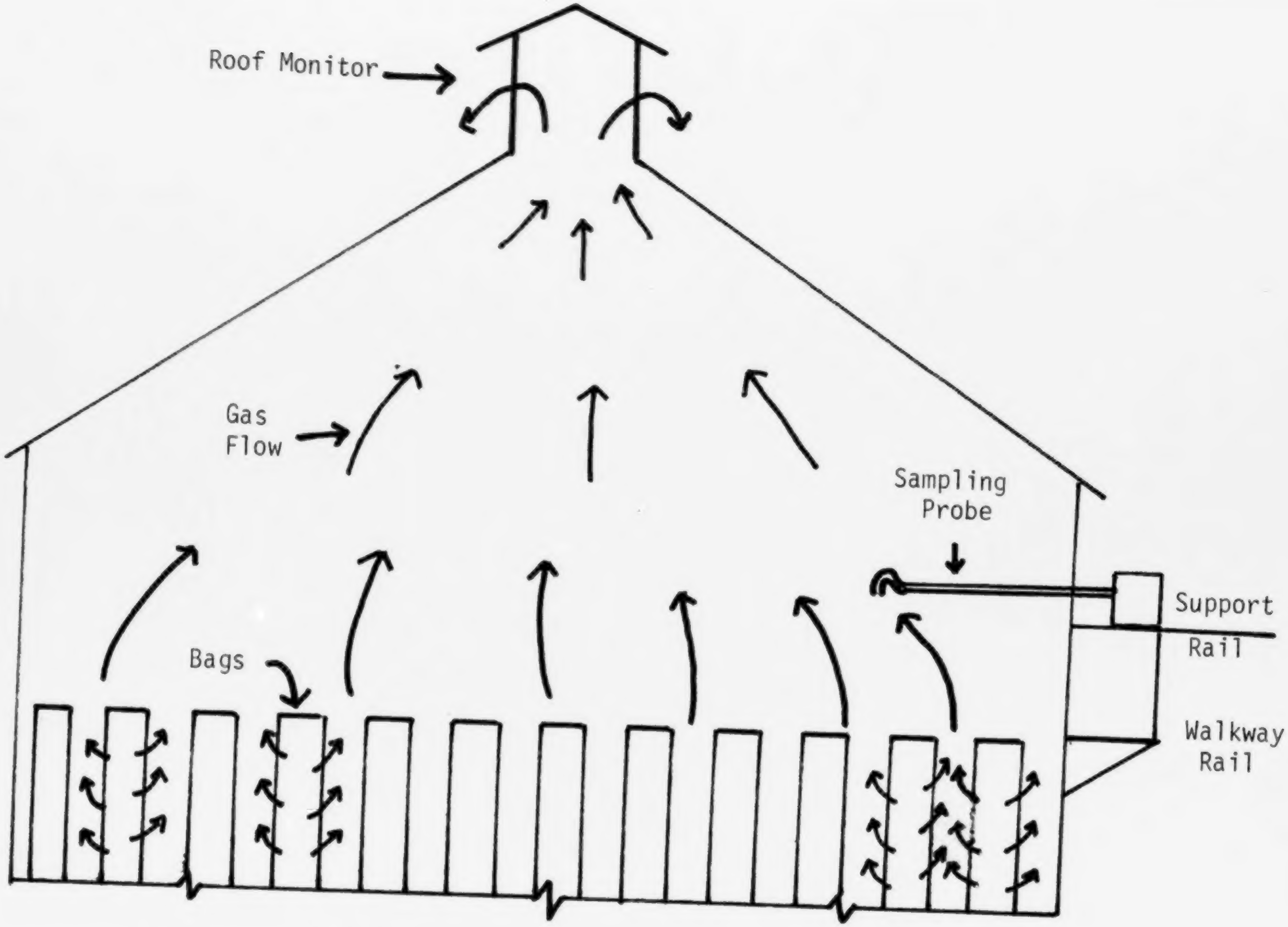
Roof Monitor
Gas
Flow
Sampling
Probe
Support
Rail
Bags
Walkway
Rail

Figure 11. Elevation section of baghouse outlet.

Sampling at both locations was done by EPA Methods 1-5, as applicable, (see Appendix for details of test methods) with the same exceptions given in Section 7 (page 99).

Simultaneously with the sampling activity, process operating information was also collected and included:

1. Raw material type and amount--from plant records.
2. Furnace power consumption--instantaneous and cumulative, read from meters in the control room.
3. Weight of alloy produced and chemical analysis--from plant records.
4. Time and duration of tapping.
5. Baghouse pressures, and inlet temperature.
6. Furnace operating conditions.

Given in Tables 50 and 51 are the pertinent sampling data for the baghouse inlet and outlet. The outlet gas flow rate was calculated assuming 30 percent of the gas leaving the baghouse was ambient air drawn in through the grates. We were forced to make an assumption about the amount of air drawn in through the grates since it was discovered after the test that the temperature reading thought to be after the heat exchangers was for a different location. The 30 percent figure was arrived at by engineering judgment, considering the infiltration air rates determined for the baghouses tested at Interlake, Inc. and SAMANCOR, the exit gas temperatures for these baghouses, and the ambient temperatures.

Given in Table 52 are the raw material consumption data. Data are given for all three shifts each day so that any variability in operating conditions can be identified. Raw material consumption was low (compared to the other shifts) on the 8-4 shift both days of testing. On 3/17/81, power was being consumed at a fairly normal rate but alloy production was somewhat low indicating the mix may have contained too much coal. This condition resulted in low consumption of raw material. On 3/18/81, the furnace was burned down for sounding followed by furnace maintenance. Sounding means the furnace was operated without mix being added until the raw material level in the furnace was low enough to measure electrode length. This occurred between 8:30 and

## TABLE 50. BAGHOUSE INLET SAMPLING DATA

| Run No.<br>Date | 1<br>3/17/81 | 2<br>3/17/81 | 3<br>3/17/81 | 4<br>3/18/81 | 5<br>3/18/81 |
|---|---|---|---|---|---|
| Start Time | 0937 | 1315 | 1615 | 1315 | 1635 |
| Stop Time | 1145 | 1520 | 1805 | 1513 | 1835 |
| Net Sampling Time, min | 90 | 90 | 90 | 90 | 90 |
| Stack Temperature, °C | 177 | 180 | 171 | 176 | 184 |
| Stack Flow Rate $dsm^3/min$ | 6,994 | 7,487 | 8,165 | 7,551 | 7,905 |
| Stack Flow Rate $Am^3/min$ | 11,201 | 12,049 | 12,848 | 12,071 | 12,950 |
| Volume Collected $dsm^3$ | 1.5423 | 1.6746 | 1.7686 | 1.6568 | 1.7681 |
| Percent Isokinetic | 98.0 | 99.4 | 96.3 | 97.5 | 99.4 |

## TABLE 51. BAGHOUSE OUTLET SAMPLING DATA

| Run No.<br>Date | 1<br>3/17/81 | 2<br>3/17/81 | 3<br>3/18/81 |
|---|---|---|---|
| Start Time | 0945 | 1355 | 1257 |
| Stop Time | 1252 | 1659 | 1557 |
| Net Sampling Time, min | 160 | 160 | 160 |
| Stack Temperature, °C | 82 | 93 | 96 |
| Volume Collected, $dsm^3$ | 3.2774 | 3.2030 | 3.2358 |
| Gas Flow Rate,[a] $dsm^3/min$ | 9,990 | 11,180 | 10,790 |
| Compartments Sampled | 1, 2, 3, 4 | 5, 6, 7, 8 | 8, 9, 10, 11 |

[a] Assuming 30 percent of baghouse outlet flow is ambient air.

## TABLE 52. RAW MATERIAL CONSUMPTION,[a] FURNACE NO.2

| Date | 3/17/81 | 3/17/81 | 3/17/81 | 3/18/81 | 3/18/81 | 3/18/81 |
|---|---|---|---|---|---|---|
| Shift | 12-8 | 8-4 | 4-12 | 12-8 | 8-4 | 4-12 |
| Quartz No.120 | 54.86 | 38.49 | 65.64 | 58.52 | 39.62 | 59.94 |
| Si Remelts | 5.15 | 3.63 | 4.10 | 5.79 | 3.95 | 8.20 |
| Iron Scrap No.155 | 17.3 | 15.33 | -- | -- | -- | 31.57 |
| Iron Scrap No.154 | 13.08 | 4.62 | 36.16 | 32.40 | 22.76 | 1.77 |
| Coal No.103 | 6.82 | 5.04 | 8.72 | 7.33 | 4.99 | 8.04 |
| Coal No.101 | 20.89 | 13.47 | 23.80 | 20.82 | 13.83 | 21.08 |
| Woodchips | 20.57 | 14.58 | 25.48 | 23.00 | 15.78 | 24.01 |
| Total | 139.19 | 95.16 | 163.91 | 147.86 | 100.93 | 154.61 |

11:55 a.m. No testing occurred until the furnace returned to stable operation.

A small amount of silicon remelts are recycled to the furnace for recovery. None of the calculated results have been corrected for this recycle. The weight of electrode consumed is also not included in the table since determining this value over a short time period is difficult and highly inaccurate. For those wishing to include electrode consumption, plant records for 3/14/81 to 3/18/81 indicate an electrode consumption rate of about 3.6 Kg/MW-hr.

Given in Table 53 are the furnace electric power consumption meter readings taken in the control room. Data listed for midnight and 8 a.m. were recorded by plant operators. The low rate of power consumption indicated for the period 800-1300 hours on 3/18/81 was due to the furnace shutdown noted above.

Given in Table 54 are the times at which tapping occurred during the two days of testing, the weight of alloy tapped, and the tap analysis. Because of variability in tapping completeness and other plant procedures, it is not advisable to attempt to correlate power consumption and tap weights for individual taps.

## 8.4 TEST RESULTS

### 8.4.1 Gas Analysis

During Run No.3 at the baghouse inlet a gas sample was collected and an Orsat gas analysis performed. The results are given in Table 55.

The data suggest that fairly complete combustion of the furnace gas is occurring. As noted previously, the reaction gases burn above the surface of the raw material charged into the furnace. These data also show that a large volume of ambient air, relative to the gas produced by the furnace, is drawn into the furnace fume collecting system.

### 8.4.2 Particulates

Given in Table 56 are the results obtained for particulate matter in the baghouse inlet gas. Particulate concentrations in the gas averaged about 218 mg/dsm$^3$ with an approximate range of 390-700 mg/dsm$^3$. Total

## TABLE 53. POWER CONSUMPTION RECORD
## CONTROL ROOM METER READINGS

| Date | Time | Furnace No.2 | |
|---|---|---|---|
| | | Total MW-hrs | Instantaneous, MW |
| 3/17/81 | 000 (Midnight) | 49,078 | |
| | 800 | 49,335 | |
| | 929 | | 25.48 |
| | 950 | 49,388 | 28.0 |
| | 1000 | | 29.78 |
| | 1005 | 49,395 | |
| | 1014 | | 28.49 |
| | 1023 | | 25.53 |
| | 1030 | | 22.8 |
| | 1035 | 49,410 | 29.4 |
| | 1040 | | 30.6 |
| | 1128 | | 29.76 |
| | 1200 | 49,453 | 30.7 |
| | 1224 | | 30.69 |
| | 1350 | | 32.62 |
| | 1400 | | 34.31 |
| | 1405 | 49,521 | |
| | 1445 | | 33.21 |
| | 1500 | | 31.62 |
| | 1546 | | 32.21 |
| | 1600 | 49,583 | 32.5 |
| | 1646 | | 31.87 |
| | 1710 | 49,623 | 32.8 |
| | 1738 | | 31.35 |
| | 1810 | 49,653 | 29.9 |
| | 1822 | 49,661 | 30.37 |
| 3/18/81 | 000 (Midnight) | 49,835 | |
| | 800 | 50,101 | |
| | 1300 | 50,188 | 31.47 |
| | 1330 | 50,202 | 29.86 |
| | 1400 | 50,220 | 33.29 |
| | 1430 | 50,239 | 30.49 |
| | 1500 | 50,251 | 33.11 |
| | 1530 | 50,271 | 30.05 |
| | 1600 | 50,282 | 31.18 |
| | 1639 | 50,308 | 35.16 |
| | 1733 | 50,339 | 32.58 |
| | 1807 | 50,351 | 32.08 |
| | 2400 | 50,555 | |

## TABLE 54. TAPPING DATA

| Date | Tap Time | Tap Weight (kg) | Analysis, % Si | Ca | Cr | Al |
|---|---|---|---|---|---|---|
| 3/17/81 | 000-030 | 6,577 | 48.8 | 0.27 | 0.16 | 1.01 |
| | 115-140 | 8,981 | 49.0 | 0.28 | 0.16 | 0.99 |
| | 225-250 | 10,932 | 48.0 | 0.37 | 0.16 | 1.22 |
| | 335-355 | 7,802 | 48.2 | 0.37 | 0.16 | 1.26 |
| | 440-500 | 8,301 | 47.0 | 0.43 | 0.15 | 1.28 |
| | 545-605 | 10,251 | 47.4 | 0.60 | 0.15 | 1.52 |
| | 650-715 | -- | 46.8 | 0.59 | 0.14 | 1.52 |
| | Shift Total | 52,844 | | | | |
| | 810-840 | 2,608 | 46.6 | 0.52 | 0.21 | 1.44 |
| | 940-? | 5,262 | 46.0 | 0.57 | 0.22 | 1.56 |
| | 1115-? | 7,938 | 45.0 | 0.58 | 0.21 | 1.62 |
| | ? -1245 | 9,798 | 44.2 | 0.57 | 0.21 | 1.58 |
| | 1345-? | 6,895 | 46.0 | 0.48 | 0.21 | 1.67 |
| | ?-1520 | 7,574 | 45.6 | 0.47 | 0.19 | 1.60 |
| | | 10,954 | | | | |
| | Shift Total | 51,029 | | | | |
| | 1615-1640 | 14,356 | 46.4 | 0.48 | 0.20 | 1.5 |
| | 1730-1755 | 7,257 | 46.6 | 0.46 | 0.19 | 1.3 |
| | 1840-1905 | 6,895 | 46.8 | 0.49 | 0.20 | 1.54 |
| | 1945-2015 | 7,121 | 48.6 | 0.28 | 0.19 | 1.0 |
| | 2100-2125 | 11,249 | 48.0 | 0.28 | 0.20 | 0.98 |
| | 2155-2220 | 8,709 | 48.0 | 0.48 | 0.20 | 1.23 |
| | 2300-2320 | -- | 47.8 | 0.44 | 0.19 | 1.16 |
| | Shift Total | 55,588 | | | | |
| | Day Total | 159,460 | | | | |
| 3/18/81 | 015-040 | 8,845 | 47.0 | 0.51 | 0.22 | 1.31 |
| | 140-? | 9,435 | 47.2 | 0.51 | 0.21 | 1.33 |
| | 300-? | 9,321 | 47.6 | 0.25 | 0.25 | 0.94 |
| | 400-? | 6,895 | 47.2 | 0.25 | 0.21 | 0.90 |
| | 500-? | 7,212 | 47.4 | 0.30 | 0.26 | 1.00 |
| | 605-? | 4,944 | 46.6 | 0.23 | 0.22 | 0.95 |
| | 700-? | Lost part of tap | 48.0 | 0.28 | 0.24 | 0.95 |
| | Shift Total | 46,652 | | | | |
| | 810-900 | 4,491 | 45.8 | 0.39 | 0.19 | 1.25 |
| | 930-1010 | 8,255 | 47.8 | 0.29 | 0.27 | 1.05 |
| | 1230-1300 | 9,798 | 48.0 | 0.22 | 0.24 | 0.89 |
| | 1345-1415 | 8,029 | 48.6 | 0.14 | 0.24 | 0.70 |
| | 1450-1520 | 9,049 | 48.0 | 0.17 | 0.27 | 0.85 |
| | Shift Total | 39,621 | | | | |

continued

TABLE 54 (continued).

| Date | Tap Time | Tap Weight (kg) | Analysis, % | | | |
|---|---|---|---|---|---|---|
| | | | Si | Ca | Cr | Al |
| 3/18/81 | 1610-1625 | 9,344 | 46.8 | 0.31 | 0.25 | 1.05 |
| | 1715-1745 | 8,732 | 47.8 | 0.28 | 0.24 | 0.92 |
| | 1830-1850 | 11,249 | 47.8 | 0.33 | 0.23 | 0.95 |
| | 1930-1950 | 9,435 | 47.4 | 0.18 | 0.29 | 0.83 |
| | 2030-2100 | 8,800 | 48.0 | 0.24 | 0.23 | 0.88 |
| | 2145-2215 | 9,276 | 49.0 | 0.23 | 0.27 | 0.91 |
| | 2300-2320 | -- | 47.4 | 0.18 | 0.26 | 0.80 |
| | Shift Total | 56,835 | | | | |
| | Day Total | 143,108 | | | | |

TABLE 55. ORSAT GAS ANALYSIS, BAGHOUSE INLET

| Component | Percent by Volume[+] |
|---|---|
| $N_2$ | 80.0 |
| $O_2$ | 18.8 |
| $CO_2$ | 1.2 |
| CO | 0.0 |

[+] Dry basis.

## TABLE 56. PARTICULATES, BAGHOUSE INLET

| Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Generated[a] per hour, Kg | Average Load[a] During Test MW-hr/hr | Kg Generated per MW-hr | Kg Generated[b] per Mg Feed | Kg Generated[c] per Mg Alloy |
|---|---|---|---|---|---|---|---|
| 1 | 1,073.8 | 696.2 | 292.2 | 30.0 | 9.74 | 25.38 | 47.34 |
| 2 | 1,004.8 | 600.0 | 269.5 | 32.5 | 8.29 | 21.61 | 40.30 |
| 3 | 852.1 | 481.8 | 236.0 | 32.3 | 7.31 | 11.23 | 33.12 |
| 4 | 700.4 | 422.7 | 191.5 | 33.2 | 5.77 | 10.34 | 26.35 |
| 5 | 689.8 | 390.1 | 185.0 | 32.6 | 5.67 | 10.02 | 27.26 |
| Average, All Runs | | 518.2 | 234.8 | | 7.36 | 15.72 | 34.87 |

[a] Per operating hour.

[b] Total Mg fed on shift divided by total MW-hr on shift to get Mg feed/MW-hr. These numbers multiplied by average load during test to get Mg fed per test hour. These numbers then divided into Kg particulate generated per hour.

[c] Calculated as in note b, substituting total alloy tapped for Mg feed.

particulate generated by the furnace averaged about 235 Kg per operating hour with a range of 185-292 Kg/hour. In terms of operating parameters, the average amount of particulate generated was about 7.4, 15.7, and 35.0 Kg per MW-hr, per Mg raw material feed, and per Mg alloy produced, respectively.

The variability in furnace fume generation rate does not seem to correlate with the operating parameters of average load, rate of raw material feed, or rate of alloy production. Tapping fumes are also unlikely to be the cause of the variability since two taps were included in each of the first four inlet runs, one tap in Run No.5. Furnace operating conditions on 3/17/81 during inlet Runs 1, 2, and 3 were fairly, but not unusually rough. The furnace appeared to be slightly overcoked (ratio of coal to quartz too high) and the plant personnel felt that one or more electrodes may have been too long. The process observers noted that the number and severity of furnace blows, which were fairly frequent and severe during Run No.1, decreased steadily through Runs No.2 and 3. The morning of 3/18/81, the furnace was "burned down" (operated without adding raw material to lower the level of material in the furnace) to sound (measure the length of) the electrodes. No testing occurred during this period. After the furnace was returned to normal operation, the process observers noted that the flame distribution over the surface of the furnace charge was much more uniform than the preceding day. In addition, the number and severity of furnace blows was significantly less than on the preceding day.

It appears, therefore, that the primary factor affecting the variability in fume generation rate is the incidence and severity of furnace blows. Furnace blows are probably more related to sublties of furnace operation (quality of feed, tap to hearth voltage, local variations in porosity of furnace charge, electrode length, and the skill of the furnace operator) than to such coarse features as total power input or amount of raw material fed, assuming, of course, that the furnace is kept within design limits and sufficient raw material is kept in the furnace. Note that the discussion here is for the variability in fume generation rate for a particular furnace making a particular product. We do not intend to imply that the difference in rate of fume generation among different furnaces producing different products is solely related to the incidence of furnace blows.

Given in Table 57 are the particulate data for the baghouse outlet tests. The average particulate concentration in the baghouse outlet was about 10 $mg/dsm^3$, with an approximate range of 6 to 13 $mg/dsm^3$. The amount of particulate emitted to the atmosphere was about 6.3 Kg/operating hour, with an approximate range of 3.7 to 8.4 Kg/operating hour. In terms of operating parameters, particulate emissions averaged about 0.20 Kg/MW-hr, 0.37 Kg/Mg of raw material fed, and 0.93 Kg/Mg of alloy tapped. Note that all of these numbers, except particulate concentration in the gas, are based on the assumption that 30 percent of the baghouse outlet gas flow rate is ambient air drawn in through the baghouse cooling grates. This number is consistent with that determined for other baghouses operating at the same temperature. If one assumed zero percent infiltration of ambient air (an impossible situation), the particulate emission rates would be 30 percent less than stated. In any event, the average emission rate (Kg/Mw-hr) is less than the Federal New Source Performance Standard (does not apply to the furnace) of 0.23 Kg/MW-hr.

Since no particularly unusual furnace operating conditions existed during the tests, it is probable that the average of the runs represents a fairly good approximation of the actual amount of particulate emitted from the baghouse.

Given in Table 58 are the calculated baghouse particulate capture efficiencies. The overall capture efficiency for the three tests was over 97 percent with a range of 95.6 percent to 98.7 percent. There was no evidence of bag failure during any of the tests.

Based on the test data, about 5480 Kg (6.05 tons) of particulate from furnace No.2 was captured by the baghouse (including multiclone pre-collector) for each 24 hours of operation.

### 8.4.3 Organic Matter

Given in Table 59 are the results obtained for organic matter in the baghouse inlet gas. The organic concentration in the baghouse inlet averaged about 48 $mg/dsm^3$ for the five runs with a range of 9 to 86 $mg/dsm^3$. Total organic generated by the furnace averaged 22 Kg/hour, with a range of 4 to 39 Kg/hr. Thus, the furnace was generating about 9 percent as much

## TABLE 57. PARTICULATES, BAGHOUSE OUTLET

| Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Emitted per hour Kg | Average Load During Test MW-hr/hr | Emitted per MW-hr Kg | Emitted per Mg feed Kg | Emitted per Mg Alloy Kg |
|---|---|---|---|---|---|---|---|
| 1 | 20.1 | 6.13 | 3.67 | 31.3 | 0.117 | 0.31 | 0.57 |
| 2 | 32.7 | 10.21 | 6.85 | 33.1 | 0.207 | 0.32 | 0.94 |
| 3 | 41.8 | 12.92 | 8.36 | 31.3 | 0.267 | 0.47 | 1.26 |
| Average, All Runs |  | 9.75 | 6.29 |  | 0.197 | 0.37 | 0.92 |

See Table 56 for calculation methods.

TABLE 58. BAGHOUSE PARTICULATE CAPTURE EFFICIENCY

| Outlet Run | Inlet Run Number Used in Calculation | Baghouse[a] Particulate Capture Efficiency, % |
|---|---|---|
| 1 | 1 | 98.7 |
| 2 | 2,3[b] | 97.3 |
| 3 | 4 | 95.6 |
| Average (all runs) | | 97.2 |

[a] Calculated using the respective calculated Kg generated and emitted per hour. Calculations based on particulate concentrations in the respective gases will overstate baghouse efficiency because of additional air drawn into the baghouse through the cooling air grates.

[b] A simple average of the particulate generation rate in inlet Runs No.2 and 3 was used. Outlet Run No.2 overlapped inlet Runs No.2 and 3.

## TABLE 59. ORGANIC, BAGHOUSE INLET AND OUTLET

| Location | Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Generated per hour, Kg | Generated per MW-hr, Kg | Generated per Mg Feed, Kg | Generated per Mg Alloy, Kg |
|---|---|---|---|---|---|---|---|
| Inlet | 1 | 81 | 52.5 | 22.0 | 0.733 | 1.9 | 3.6 |
| | 2 | 15 | 8.96 | 4.02 | 0.124 | 0.32 | 0.60 |
| | 3 | 92 | 52.0 | 25.5 | 0.789 | 1.2 | 3.6 |
| | 4 | 143 | 86.3 | 39.1 | 1.18 | 2.11 | 5.4 |
| | 5 | 74 | 41.9 | 19.9 | 0.61 | 1.08 | 2.9 |
| Average, all runs | | | 48.3 | 22.1 | 0.69 | 1.3 | 3.2 |
| | | | | Emitted per hour, Kg | Emitted per MW-hr, Kg | Emitted per Mg Feed, Kg | Emitted per Mg Alloy, Kg |
| Outlet | 1 | 58 | 17.7 | 10.6 | 0.339 | 0.88 | 1.6 |
| | 2 | 81 | 25.3 | 17.0 | 0.514 | 0.79 | 2.3 |
| | 3 | 87 | 26.9 | 17.4 | 0.556 | 0.99 | 2.6 |
| Average, all runs | | | 23.3 | 15.0 | 0.47 | 0.89 | 2.2 |

organic as particulate matter. Over 80 percent of the organic was found in the XAD-2 resin. Thus, less than 20 percent of the organic matter was adsorbed on the particulate.

In terms of operating parameters, the organic matter generation rates were 0.69 Kg/MW-hr, 1.3 Kg/Mg raw material fed, and 3.2 Kg/Mg alloy tapped. The rate of organic generation does not seem to correlate well with any of the operating parameters. There is a weak suggestion in the data that less organic matter is generated during periods of rough (i.e., furnace blows) furnace operation.

Included in Table 59 are the organic results for the baghouse outlet. The average concentration in the outlet gas was 23 mg/dsm$^3$. Over 90 percent of the organic emitted was found in the XAD-2 resin. Thus, less than 10 percent of the emitted organic matter was adsorbed on the particulate matter. Significantly improving the baghouse particulate collection efficiency would, therefore, have little effect on organic emission rates. Organic emissions (15 Kg/hr) exceed particulate emissions (6.3 Kg/hr) by about a factor of 2.5.

In terms of operating parameters, emission rates were about 0.5 Kg/MW-hr, 0.9 Kg/Mg raw material fed, and 2.2 Kg/Mg alloy tapped. There is relatively little variability in the results obtained.

Given in Table 60 are the baghouse capture efficiencies for the organic matter. The measured capture efficiency for outlet run No.2 is negative. Similar type results were obtained for baghouse at the other two open furnaces tested. In this particular case, the results are obtained because of the low amount of organic detected in inlet Run No.2. Outlet run No.2 overlapped inlet runs No.2 and 3. Possible reasons for this type of result were discussed in Section 7.4.3.

TABLE 60. BAGHOUSE ORGANIC CAPTURE EFFICIENCIES

| Outlet Run Number | Inlet Run Number | Capture Efficiency for Organics, % |
|---|---|---|
| 1 | 1 | 52 |
| 2 | 2, 3 | -15 |
| 3 | 4 | 55 |
| Average | | 31 |

### 8.4.4 Benzo(a)Pyrene

Given in Table 61 are the results obtained for BaP in the baghouse inlet. BaP was detected in two of the five inlet runs. The average BaP concentration in the baghouse inlet gas was 0.21 $\mu g/dsm^3$ or about 4 x $10^{-4}$ percent of the total organic. For the two runs in which BaP was detected, all of the BaP was adsorbed on the particulate matter. The furnace generated about 0.08 grams per furnace operating hour or 3 x $10^{-3}$ g/MW-hr, 5 x $10^{-3}$ g/Mg raw material fed, and 1.4 x $10^{-2}$ g/Mg alloy tapped.

Given in Table 61 are the BaP results obtained for emissions from the baghouse. No BaP was detected in any of the three tests. Analytical detection limit for BaP in the outlet gas was about 0.15 $\mu g/dsm^3$.

### 8.4.5 BaP in Baghouse Collected Particulate

A sample was obtained of the particulate matter captured by the baghouse. In addition to leaching tests, discussed below, the sample was analyzed for BaP content. The dust contained 0.022 μg BaP/g. The plant disposes of the dust off-site.

### 8.4.6 Leaching Tests, Baghouse Dust

The baghouse dust was analyzed for nine metals on EPA's Priority Pollutant list. At least five (Be, Cd, Cr, Pb, Se) of the elements are present (see Table 62) in concentrations which may be of some concern.

## TABLE 61. BaP, BAGHOUSE INLET AND OUTLET

| Location | Run Number | μg BaP Captured | Concentration in Gas, μg/dsm$^3$ | Generated per hour, g | Generated per MW-hr, g | Generated per Mg Feed, g | Generated per Mg Alloy, g |
|---|---|---|---|---|---|---|---|
| Inlet | 1 | ND[a] | - | - | - | - | - |
| | 2 | ND | - | - | - | - | - |
| | 3 | ND | - | - | - | - | - |
| | 4 | ∼0.4[b] | ∼0.2 | ∼0.1 | ∼0.003 | ∼0.005 | ∼0.01 |
| | 5 | 1.5 | 0.85 | 0.40 | 0.012 | 0.022 | 0.059 |
| Average, all runs | | | ∼0.21 | ∼0.082 | ∼0.003 | ∼0.005 | ∼0.014 |
| | | | | Emitted per hour, g | | | |
| Outlet | 1 | ND | - | - | | | |
| | 2 | ND | - | - | | | |
| | 3 | ND | - | - | | | |

[a] ND = None detected. Detection limits for inlet samples averaged 0.3 μg/dsm$^3$ and 0.15 μg/dsm$^3$ for outlet samples.

[b] Measured BaP concentration was only slightly below lowest calibration point (0.5 μg).

TABLE 62. LEACHING TESTS, OPEN 50 PERCENT FeSi FURNACE BAGHOUSE DUST

| Element | Concentration in Original Sample, μg/g Solid | Concentration in Leachate, mg/L | Amount Leached, μg/g Solids | % of Element |
|---|---|---|---|---|
| Antimony | 4.32 | $3.67 \times 10^{-2}$ | 0.734 | 17 |
| Arsenic[a] | 145 | $<5 \times 10^{-2}$ | <1 | 0.7 |
| Beryllium | 0.318 | $5 \times 10^{-4}$ | $9.9 \times 10^{-3}$ | 3.1 |
| Cadmium | 27.4 | 0.443 | 8.86 | 32.3 |
| Chromium | 239 | $2.77 \times 10^{-2}$ | 0.555 | 0.23 |
| Lead | 2680 | $<1 \times 10^{-3}$ | $<2 \times 10^{-2}$ | $7 \times 10^{-4}$ |
| Mercury | <0.62 | $<1.2 \times 10^{-2}$ | <0.25 | ? |
| Selenium | 75.7 | 0.28 | 5.61 | 7.4 |
| Thallium | 2.96 | $2.29 \times 10^{-3}$ | $4.59 \times 10^{-2}$ | 1.6 |

[a] Possible analytical interference.

Arsenic may also be of some concern but this cannot be stated with confidence because of an analytical interference.

The dust was then subjected to leaching following procedures given in the Federal Register 40 CFR Part 261, Appendix II, May 19, 1980. The leachate analysis is given in column 3 of Table 62. None of the elements equal or exceed the permissible concentrations given in 40 CFR Part 261.24. Thus, on this basis, the solid is nonhazardous.

Given in the last columns of the table are the actual amount extracted and the percentage of the element extracted. In general, less than about three percent of the element was extracted. Notable exceptions are antimony (17 percent), cadmium (32 percent) and selenium (7.4 percent).

## 9.0 TESTING OF COVERED FURNACE PRODUCING 50 PERCENT Si

These tests were done on furnace No.20 and associated facilities at Union Carbide Corporation's plant (now owned by Elkem Metals Company) in Ashtabula, OH on November 11, 12, and 13, 1980.

### 9.1 SITE DESCRIPTION

### 9.1.1 General Plant

There are five submerged arc furnaces at the plant. Three of the furnaces are used to produce ferrosilicon products, 50 percent grade being the most common. Of these three, two are of covered (mix-sealed) design, the third an open design. Design furnace power rating for these three furnaces are 22, 45, and 50 MW. The other two furnaces, both of covered (mix-sealed) design and each rated at 22 MW, are used to produce calcium carbide.

Fumes generated by the open furnace are controlled by a baghouse. Scrubbers are used on all of the covered furnaces to treat gas from beneath the furnace covers. Fumes escaping the furnace covers are collected by hoods above the furnaces and are treated in baghouses.

Dusts collected by the various baghouses are slurried with water in small buildings adjacent to each baghouse. The slurry is discharged into the wastewater ponds (either directly or after passing through a clarifier). Discharge water from the scrubbers, part of which also passes through a clarifier, also is discharged to the ponds.

The wastewater treatment area is composed of four ponds (see Figure 12). Slurries from the ferroalloy operations flow into the west pond (4B). Slurry from the calcium carbide operations flows into the east pond (4A). Solids contained in these slurries settle out in the ponds. The clarified water flows into a third pond and is chlorinated. The chlorinated wastewater flows into a fourth pond before being discharged into Lake Erie. Solids are

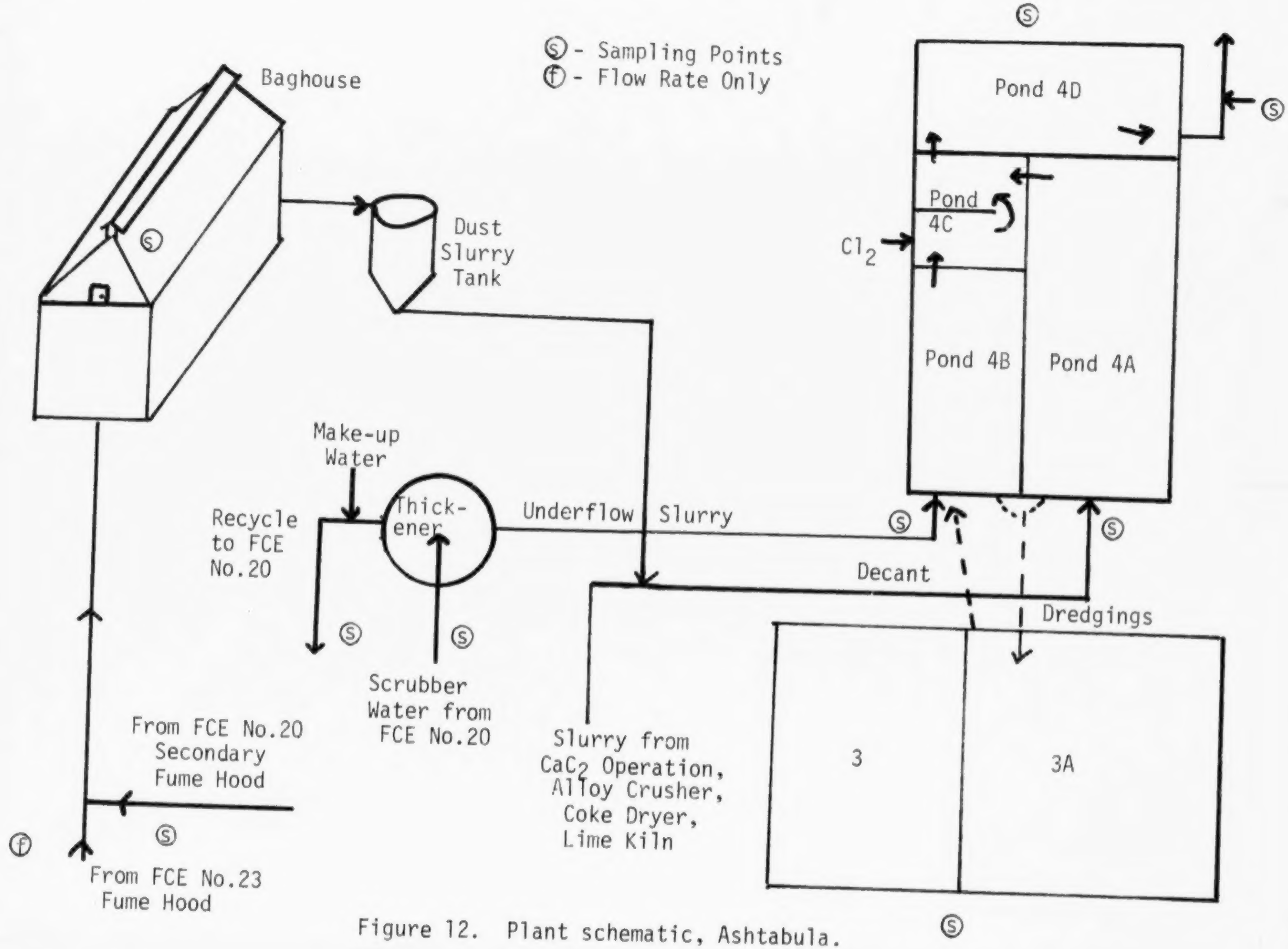
Ⓢ - Sampling Points
Ⓕ - Flow Rate Only
Baghouse
Ⓢ
Dust Slurry Tank
Make-up Water
Recycle to FCE No.20
Thick-ener
Ⓢ
Ⓢ
Scrubber Water from FCE No.20
Underflow
Slurry
From FCE No.20 Secondary Fume Hood
Ⓢ
Ⓕ
From FCE No.23 Fume Hood
Slurry from $CaC_2$ Operation, Alloy Crusher, Coke Dryer, Lime Kiln
Decant
Dredgings
Ⓢ
Pond 4D
Ⓢ
Pond 4C
$Cl_2$
Pond 4B
Pond 4A
Ⓢ
Ⓢ
3
3A
Ⓢ

Figure 12. Plant schematic, Ashtabula.

periodically removed by mudcat from the east and west ponds and pumped to landfill just south of the wastewater ponds. All solid waste from the plant wastewater treatment operations is disposed of in this landfill.

### 9.1.2 Description of Furnace No.20 and Associated Pollution Capture Equipment

Emissions testing at this plant was done on covered (mix-sealed) furnace No.20, including the scrubber treating undercover (primary) gases, and the baghouse treating fumes escaping the furnace cover (secondary). In addition, samples were taken of the wastewater discharged to the ponds, effluent from the final pond, and groundwater from up-gradient and down-gradient of the landfill--wastewater pond area (see Figures 12 and 13 for sample point locations.)

The furnace design rating is 45 MW. Three 1.40 meter (55 inch) diameter Soderberg electrodes are used for power input. The furnace cover fits tightly over the mouth of the furnace vessel and sealants are used to plug openings between the two. The electrodes extend through three holes in the furnace cover. Raw materials are added to the furnace through the annular spaces between the cover and electrodes. Sufficient raw material is maintained on the cover, piled up around the electrodes, to provide a partial gas seal hence the term, mix-sealed furnace. As a result, little ambient air is drawn into the furnace (under the cover) and little, if any, combustion of the gases produced by the furnace reactions occurs in this area. Gases are withdrawn from beneath the furnace cover through two offtakes spaced 180 degrees apart. Water is sprayed into the offtakes just outside the furnace and throughout the length of the ducts between the furnace and the scrubber. Two high pressure drop venturi scrubbers, one per offtake, wet the particulate which is then removed in separators which follow the scrubbers. About 4-12 liters (1-3 gallons) per hour of kerosene is injected into the gas at the exhaust fans (CO blowers) to assist in keeping the fan blades clean. The cleaned gas from each scrubber is pumped into the gas main which is maintained at about 90 cm of Hg (2.5 psig). The gas can either be used as fuel in the lime kiln to produce feed for the calcium carbide furnaces or routed through a bypass stack to a flare. All water from the scrubbers is

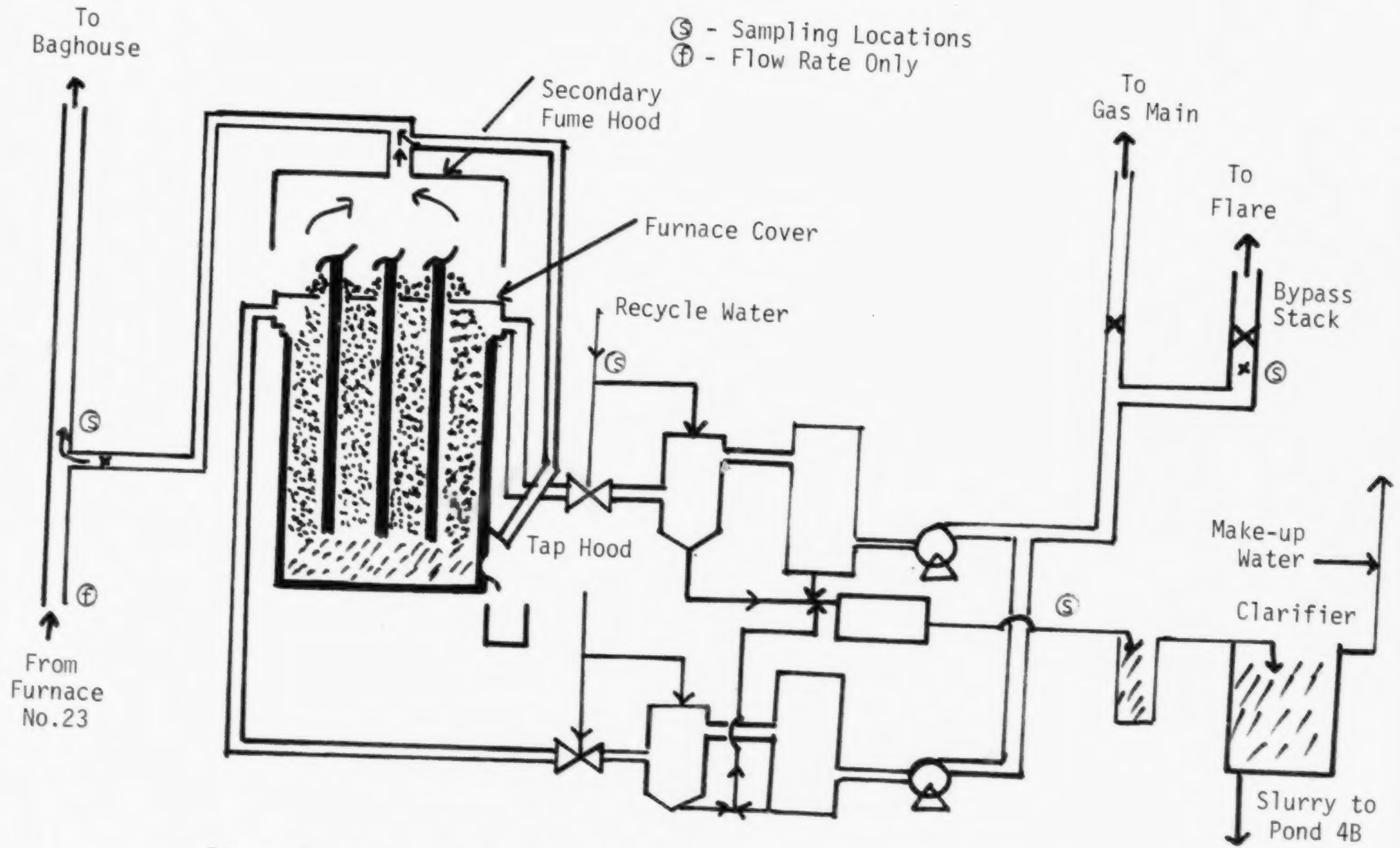
Ⓢ - Sampling Locations
Ⓕ - Flow Rate Only
To Baghouse
From Furnace No.23
Ⓢ
Ⓕ
Secondary Fume Hood
Furnace Cover
Recycle Water
Tap Hood
To Gas Main
To Flare
Bypass Stack
Make-up Water
Clarifier
Slurry to Pond 4B

Figure 13. Furnace No.20 and related pollution control equipment.

collected in a common sump and pumped to a clarifier. Underflow from the clarifier flows to wastewater pond 4B. Clarifier overflow is recycled to the scrubber. Raw lake water is added to the recycle water as make-up.

Gases escaping the furnace cover are collected by a hood mounted above the furnace. Ductwork from this hood joins the ductwork from the hood on the open furnace (No.23) just before entry to the baghouse. Furnace No.23 was not operating during the test period but ambient air was being withdrawn through the hood. The baghouse contains 14 compartments which are cleaned in sequence by a shaker type mechanism. It is designed to handle 13,450 $m^3$/min at 204°C (475,000 acfm at 400°F). Under normal operating conditions 70 percent of the gas flow is from furnace No.23 with the remaining 30 percent from the hood system on furnace No.20. Two 2000 horsepower fans force the gas through the baghouse.

The furnace has one taphole; the furnace does not rotate. A small hood swings into place over the taphole during tapping. The fumes collected are discharged into the ductwork going to the baghouse.

## 9.2 PROCESS CONTROL

The furnace is used to produce ferrosilicon products. This is accomplished by mixing sources of silicon (quartz and gravel) with scrap steel and a reductant (carbon from coke, coal, woodchips, and electrode) and heating to a sufficiently high temperature to allow the reactions

$$SiO_2 + 2C \rightarrow Si + 2CO$$
$$Fe\ (solid) \rightarrow Fe\ (liquid)$$
$$Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$$

to occur. Heat is supplied by the power input through the electrodes. A small amount of woodchips may be added to give porosity to the charge.

The furnace operation is controlled by adjusting the ratio of raw materials and varying the power input. Power input is varied by adjusting the applied voltage. The furnace is not stoked.

## 9.3 TEST DESCRIPTION

Figures 12 and 13 identify sample point locations. Figures 14-17 give more detail on the ducted fume sample point locations. Figure 4, Section 6 represents the sample point location for the baghouse outlet.

Method 5 sampling could not be done in the primary scrubber inlet gas duct because of the presence of water sprays throughout this duct. To determine the amount of materials going to the scrubber, samples were taken of the scrubber feedwater from a tap at the venturi, of the scrubber discharge water at the clarifier lift station by composite-automatic sampler, and of the scrubber outlet gas by Method 5 sampler. Scrubber water discharge flow rate was determined by calculation from dimensions of the overflow weir at the clarifier lift station. Effective width of the weir was 1.22 meters (48 inches), water height above weir 6.35 cm (2.5 inches).

As shown, the scrubber outlet sample port was located in the 35.6 cm (14 inch) inside diameter bypass duct and in the horizontal plane. Only one sample port was used at this location due to the small duct size and site conditions which prevented aligning ports at 90° angles. The nearest flow disturbances were: upstream from sample point, 15 stack diameters; downstream from sample point, 2 stack diameters. For all runs at this location, only one point at location of average velocity was sampled. Duct conditions of about 2.5 psig and 80 percent CO precluded probe movement while the furnace was operating.

Secondary fumes collected by the hood over furnace No.20 were sampled in the duct leading to the baghouse and at the baghouse outlet. The port for sampling the baghouse inlet was located in the vertical axis of the 2.04 meter (80.5 inch) inside diameter duct. Only one port was used due to the projected expense for scaffolding. The duct has a long section of horizontal run and the traverse was on the vertical axis which should cover any gradients in particle size. A horizontal traverse would likely have resulted in a bias for particulate size at that location in the duct. A 12 point traverse was completed for each run. The nearest disturbances from the sample point were: upstream from sample point, 6.7 stack diameters;

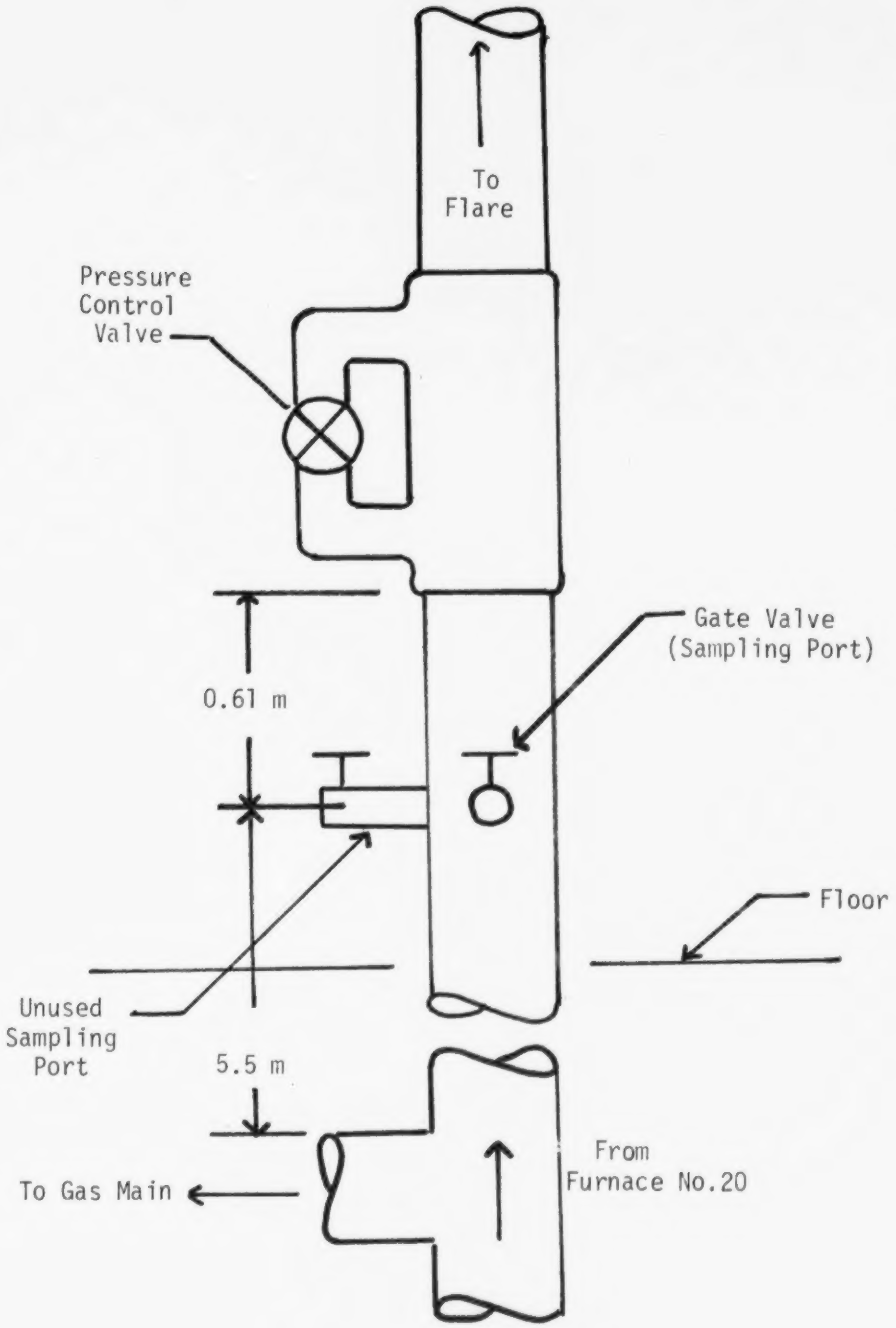
To
Flare
Pressure
Control
Valve
Gate Valve
(Sampling Port)
0.61 m
Floor
Unused
Sampling
Port
5.5 m
From
Furnace No.20
To Gas Main

Figure 14. Scrubber outlet bypass line dimensions.

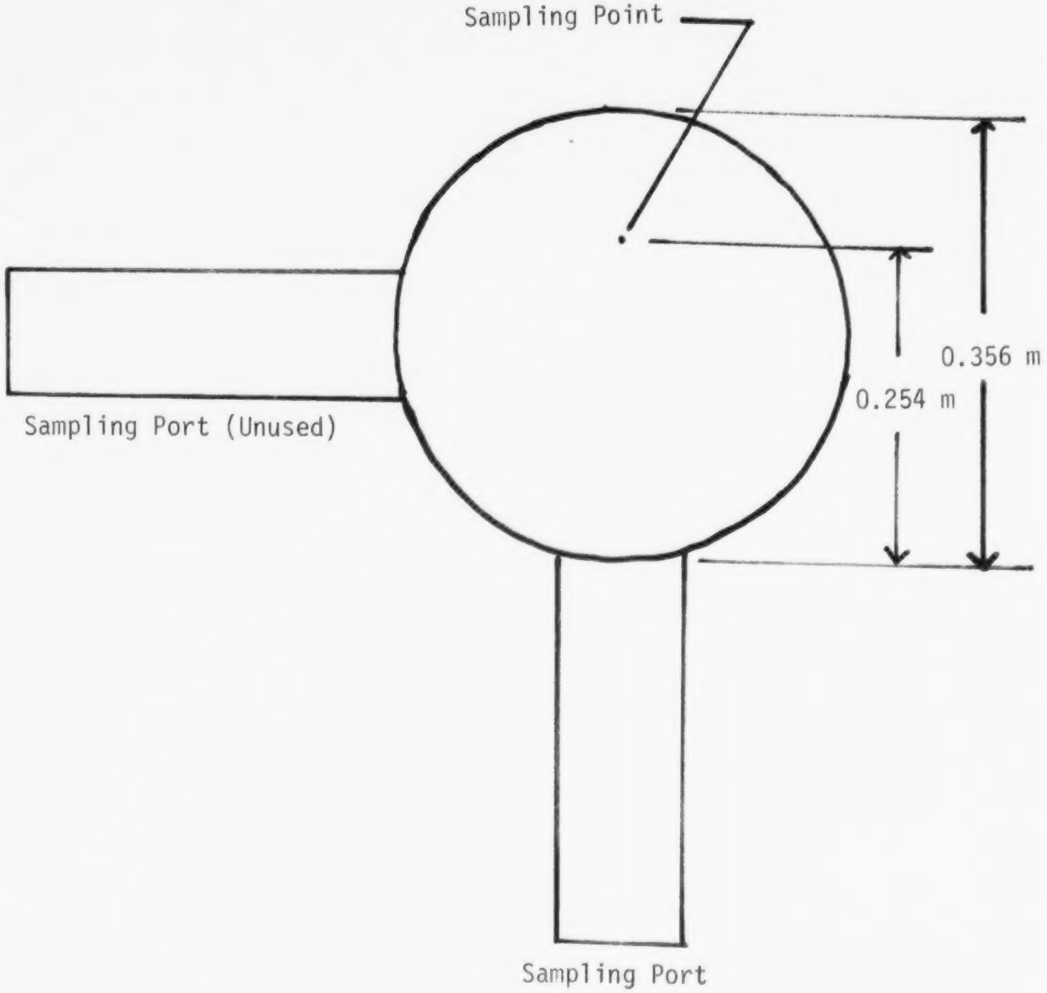
Sampling Point
0.356 m
0.254 m
Sampling Port (Unused)
Sampling Port

Figure 15. Scrubber outlet bypass line cross-section.

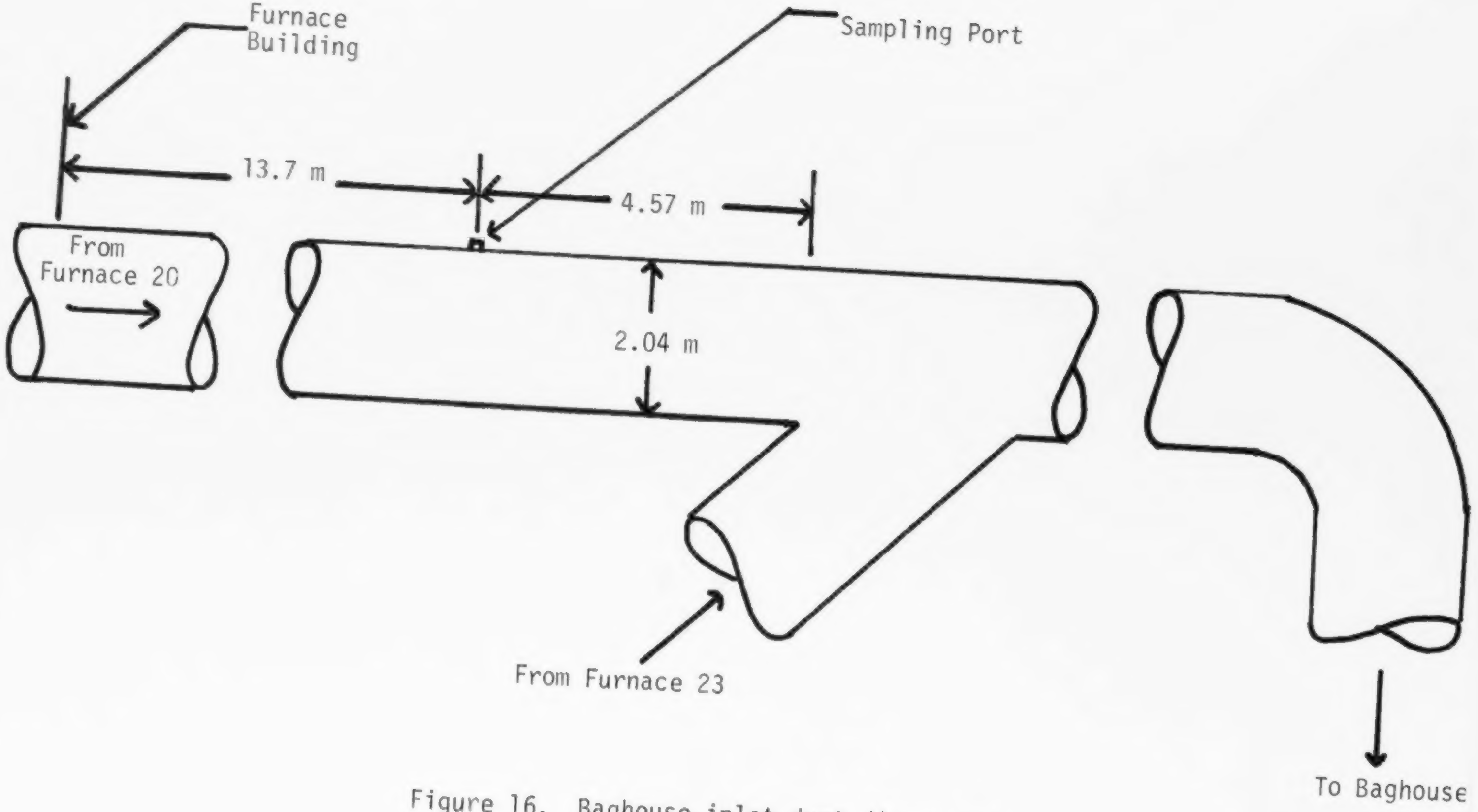
Furnace
Building
Sampling Port
13.7 m
4.57 m
From
Furnace 20
2.04 m
From Furnace 23
To Baghouse

Figure 16. Baghouse inlet duct dimensions.

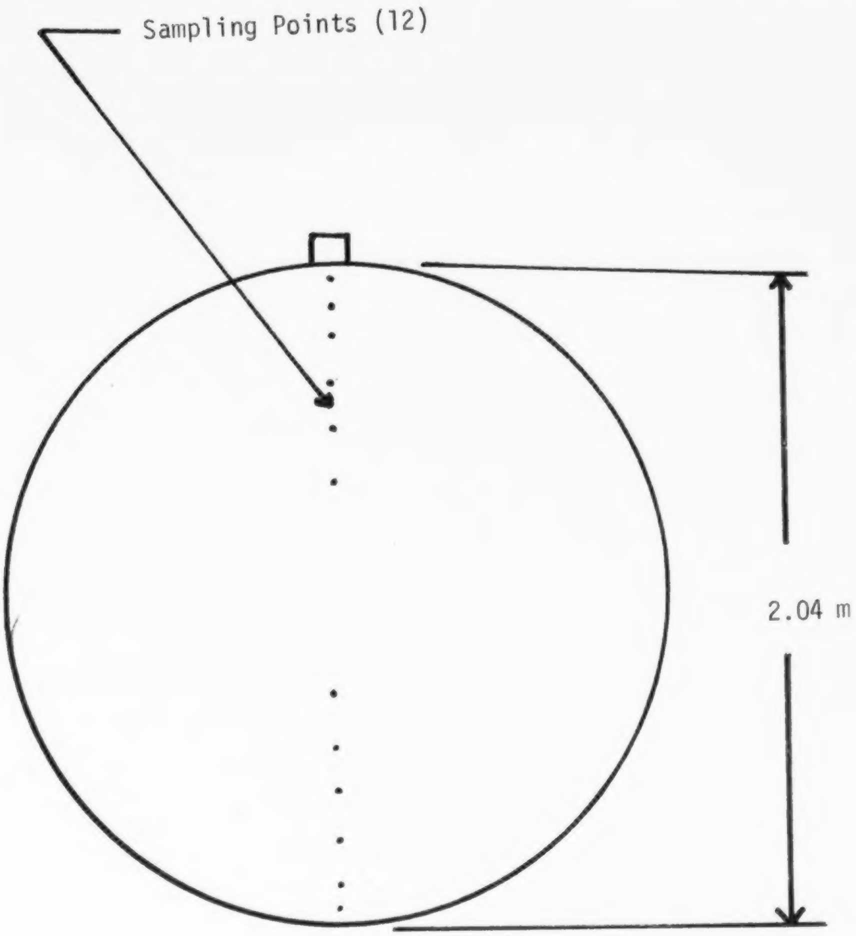
Sampling Points (12)
2.04 m

Figure 17. Baghouse inlet duct cross-section.

downstream from sample point, 2.2 stack diameters. Samples were also taken in this duct with an Anderson 2000 stack sampler to determine particle size distribution. The sample point was on the vertical axis and 30 percent of the diameter above the duct bottom.

Ports for sampling the baghouse outlet were located in four of the 14 compartments (evenly spaced, two on each side). The ports were located in the compartment doorways which open into the upper maintenance alleyway. The probe when inserted into a compartment was about 2.44 meters (8 feet inside the door and about 1 meter (4 feet) above the bag tops. Each compartment was sampled at only one point (no traverse).

A traverse of the duct leading from furnace No.23 was also made to determine gas flow rate from this source going to the baghouse. Furnace No.23 was not operating. Only ambient air was being drawn into the baghouse from this source.

Sampling at the above locations was done by EPA Methods 1-5, as applicable, (see Appendix for details of test methods) with the exceptions noted above and those given in Section 7 (page 99).

A composite sample was taken of the influent to wastewater ponds. The discharge from the final pond, 4D, was also sampled with an automatic compositing sampler.

Grab samples were collected, with assistance from plant personnel, of groundwater from points up-gradient and down-gradient of the entire solid waste disposal and wastewater treatment ponds area.

Simultaneously with the sampling activities, process operating information was also collected and included:

1. Raw material type and amount--from plant records.
2. Furnace power consumption--instantaneous and cumulative read from meters in the control room.
3. Weight of alloy produced and analysis--from plant records.
4. Time of tapping.
5. Baghouse pressures.
6. Furnace operating conditions.

Of particular note for tests done at this plant is the variation in product being made. On the first day of testing (11/11/80), furnace No.20 was producing 65 percent ferrosilicon. On this day samples were taken of the scrubber discharge water, and the scrubber outlet gas. Two runs were made at each location. The second run was aborted, however, due to a water foaming problem in the scrubber, which caused water carryover into the stack. The results of the first run are presented only to give some idea as to the variability associated with manufacture of different products since an insufficient number of runs were made to accurately establish rates. On the second day (11/12/80), the furnace was shifted from 65 percent to 50 percent ferrosilicon. Gas sampling was done only at the baghouse inlet and outlet to determine baghouse collection efficiency. On the third day (11/13/80), the plant added some offgrade silicomanganese alloy to the raw material to increase the manganese content of the product. This should have little effect on samples taken other than to introduce manganese into the fumes. Samples were taken of the scrubber waters, the clean gas discharged by the scrubbers and the baghouse inlet.

Given in Tables 63, 64, and 65 are the pertinent sampling data for the scrubber outlet, baghouse inlet, and baghouse outlet. The baghouse outlet flow rate is based on the combined flow rate from furnaces No.20 and 23.

Given in Table 66 are the raw material consumption data. Data are given only for the shifts in which testing occurred. The mix consumption figures for 11/12/80 reflect the fact that the furnace was not operating for 57 minutes of the shift. Since the computer system at the plant gives frequent updates of the amounts and types of raw material added, it was possible to present less than a full shift's data on 11/13/80. In contrast to the practice at the open furnace producing 50 percent ferrosilicon tested (described in Section 8), woodchips were not included in the raw materials fed during production of 50 percent ferrosilicon. They were added, however on 11/11-12/80 during production of the 65 percent grade and during shifting to the 50 percent grade. The weight of electrode consumed is not included in the data given since determining the value over a short time period is difficult and highly inaccurate. For those wishing to include electrode

## TABLE 63. SCRUBBER SAMPLING DATA

| Run No.<br>Date | 1<br>11/11/80 | 2<br>11/13/80 | 3<br>11/13/80 | 4<br>11/13/80 |
|---|---|---|---|---|
| Start Time | 1150 | 0925 | 1105 | 1247 |
| Stop Time | 1250 | 1030 | 1205 | 1333 |
| Net Sampling Time, min | 60 | 60 | 60 | 45 |
| Stack Temperature, °C | 52 | 89 | 81 | 88 |
| Stack Flow Rate, $dsm^3/min$ | 165.68 | 146.71 | 153.79 | 130.54 |
| Stack Flow Rate, A $m^3/min$ | 211.05 | 207.19 | 212.12 | 183.44 |
| Volume Collected, $dsm^3$ | 1.598 | 1.314 | 1.353 | 0.879 |
| Percent Isokinetic | 105.1 | 97.7 | 96.0 | 97.9 |

TABLE 64. BAGHOUSE INLET SAMPLING DATA

| Run No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Date | 11/12/80 | 11/12/80 | 11/12/80 | 11/13/80 | 11/13/80 | 11/13/80 |
| Start Time | 1015 | 1220 | 1426 | 0930 | 1110 | 1240 |
| Stop Time | 1115 | 1330 | 1530 | 1030 | 1210 | 1325 |
| Net Sampling Time, min | 60 | 60 | 60 | 60 | 60 | 45 |
| Stack Temperature, °C | 72 | 73 | 51 | 53 | 58 | 56 |
| Stack Flow Rate, $dsm^3$/min | 3,695 | 3,410 | 3,455 | 3,631 | 3,626 | 3,887 |
| Stack Flow Rate, A $m^3$/min | 4,506 | 4,170 | 3,948 | 4,205 | 4,260 | 4,542 |
| Volume Collected, $dsm^3$ | 0.956 | 0.855 | 0.847 | 0.883 | 0.887 | 0.707 |
| Percent Isokinetic | 98.9 | 95.9 | 93.7 | 92.9 | 93.5 | 92.7 |

## TABLE 65. BAGHOUSE OUTLET SAMPLING DATA

| Run No.<br>Date | 1<br>11/12/80 | 2<br>11/12/80 | 3<br>11/12/80 |
|---|---|---|---|
| Start Time | 1010 | 1225 | 1405 |
| Stop Time | 1130 | 1340 | 1517 |
| Net Sampling Time, min | 60 | 60 | 60 |
| Stack Temperature, °C | 31 | 32 | 29 |
| Stack Flow Rate, dsm$^3$/min | 10,920 | 10,630 | 10,680 |
| Volume Collected, dsm$^3$ | 1.123 | 0.781 | 0.841 |

TABLE 66. RAW MATERIAL CONSUMPTION, FURNACE NO.20 [in Kg]

| Date<br>Shift | 11/11/81<br>7-3 | 11/12/81<br>7-3 | 11/13/81<br>7-1[a] |
|---|---|---|---|
| Regular Steel | 13,202 | 19,003 | 15,222 |
| Quartz | 20,975 | 14,921 | 17,165 |
| Gravel No.1 | 20,946 | 15,003 | 17,146 |
| Gravel No.2 | 29,918 | 14,921 | 17,127 |
| Coke No.1 | 8,944 | 6,083 | 7,658 |
| Coke No.2 | 16,317 | 11,716 | 16,670 |
| Coal | 5,744 | 4,062 | 1,886 |
| Woodchips | 25,347 | 14,615 | -- |
| Steel | -- | 1,490 | 16,803 |
| SiMn | -- | -- | 5,658 |
| Total: | 132,393 | 101,814 | 115,335 |

[a] Average mix fed from 7 a.m. until 1 p.m. Not a full shift.

consumption, a nominal value of about 3 Kg/MW-hr is appropriate during production of 50 percent ferrosilicon.

Given in Table 67 are the various meter readings for electric power consumption by the furnace. All readings were from instruments in the control room. Two separate sources presented total MW-hr consumption--computer display and standard meter. Both are presented for use in calculations. The computer MW-hr reading is reset to zero at midnight of each day. The "instantaneous" readings are for the time of reading only. Averaging these numbers will not give the average power consumption for the period.

Given in Table 68 are the times at which tapping occurred, the weight of alloy tapped and the tap analysis. Note that raw material consumption data are given for the 7 a.m. - 3 p.m. time period and alloy production is given for the 8 a.m. - 4 p.m. time period.

## 9.4 TEST RESULTS

### 9.4.1 Gas Analysis

Although gas samples were taken for Orsat analysis, these analyses were not completed. The Orsat solutions had become very cold and did not perform properly. Based on discussions with plan personnel, previous test data, and engineering judgment, the following gas composition was assumed for the scrubber gas.

Assumed Gas Concentration (in % by volume)

| Component | Scrubber Outlet |
|---|---|
| $H_2O$ | 20 |
| $H_2$+ | 3 |
| $CO_2$+ | 6 |
| $O_2$+ | 0 |
| $CO^+$ | 80 |
| $H_2$ | 11 |

+Dry basis.

## TABLE 67. POWER CONSUMPTION RECORD CONTROL ROOM READINGS

| Date | Time | Furnace No.20 MW-hrs from Computer | Instantaneous MW | MW-hrs from Meter |
|---|---|---|---|---|
| 11/11/80 | 700 | | 45.2 | 41,724 |
| | 800 | | 44.9 | 41,769 |
| | 900 | | 44.5 | 41,813 |
| | 1000 | | 39.8 | 41,858 |
| | 1100 | | 45.0 | 41,899 |
| | 1200 | | 45.4 | 41,945 |
| | 1209 | 506.928 | 45.7 | |
| | 1217 | 512.828 | 45.7 | |
| | 1218 | 513.528 | 45.8 | |
| | 1232 | 523.328 | 36.6 | |
| | 1300 | | 42.7 | |
| | 1400 | | 36.8 | 42,031 |
| | 1409 | 590.002 | 39.9 | |
| | 1436 | 607.101 | 40.9 | |
| | 1452 | 617.650 | 39.8 | |
| | 1500 | | 41.6 | 42,070 |
| | 1600 | | 40.2 | 42,113 |
| | 1609 | 669.880 | | |
| | | Meter resets to 0 at midnight | | |
| 11/12/80 | 700 | | | 42,687 |
| | Down 57 min | | | |
| | 1000 | | 31.7 | 42,764 |
| | 1010 | 340.556 | 31.7 | 42,768 |
| | 1019 | | 40.0 | |
| | 1020 | 346.556 | 39.9 | 42,775 |
| | 1030 | 353.256 | 42.1 | 42,781 |
| | 1040 | 359.655 | 39.7 | 42,789 |
| | 1100 | | 39.9 | 42,802 |
| | 1151 | | 37.5 | 42,836 |
| | 1158 | 410.954 | 36.1 | |
| | 1200 | | 39.4 | 42,842 |
| | 1228 | 430.053 | 40.5 | 42,861 |
| | 1300 | | 40.0 | 42,881 |
| | 1314 | 459.940 | 38.5 | 42,889 |
| | 1330 | 468.740 | 37.7 | 42,900 |
| | 1400 | | 38.0 | 42,919 |
| | 1450 | | 36.4 | 42,951 |
| | 1454 | 521.910 | 38.7 | |
| | 1500 | | | 42,957 |
| | 1521 | Meter resets to 0 at midnight | | 42,971 |

continued

TABLE 67 (continued).

| Date | Time | Furnace No.20 MW-hrs from Computer | Instantaneous MW | MW-hrs from Meter |
|---|---|---|---|---|
| 11/13/80 | 700 | | 40.1 | 43,350 |
| | 800 | | 40.1 | 43,390 |
| | 900 | | 44.5 | 43,431 |
| | 941 | 291.075 | 42.4 | |
| | 956 | 301.574 | 40.0 | |
| | 1012 | 312.974 | 44.0 | 43,483 |
| | 1100 | | 38.8 | 43,517 |
| | 1107 | | 37.7 | 43,521 |
| | 1111 | 354.474 | 42.2 | |
| | 1149 | | 46.0 | |
| | 1150 | 382.573 | 45.5 | |
| | 1200 | | 44.5 | 43,560 |
| | 1241 | 419.372 | 41.0 | |
| | 1300 | 432.172 | 44.4 | 43,603 |

TABLE 68. TAPPING DATA

| Date | Tap Time | Analysis, % | | | | |
|---|---|---|---|---|---|---|
| | | Si | Mn | Cr | Al | Ca |
| 11/11/80 | 802 | 66.6 | 0.33 | 0.04 | 0.65 | 0.06 |
| | 926 | 67.9 | 0.31 | 0.04 | 0.66 | 0.03 |
| | 1100 | 67.9 | 0.31 | 0.04 | 0.75 | 0.13 |
| | 1212 | | | | | |
| | 1334 | 68.2 | 0.29 | 0.05 | 1.42 | 0.98 |
| | 1454 | | | | | |
| 11/12/80 | 1014 | | | | | |
| | 1125 | 51.4 | 0.45 | 0.06 | 0.94 | 0.06 |
| | 1234 | 50.2 | 0.47 | 0.06 | 0.94 | 0.21 |
| | 1337 | 49.3 | 0.47 | 0.06 | 0.94 | 0.19 |
| | 1502 | | | | | |
| 11/13/80 | 808 | 43.8 | 5.31 | 0.13 | 0.76 | 0.12 |
| | 914 | 42.3 | 6.04 | 0.14 | 0.74 | 0.14 |
| | 1017 | 42.2 | 6.37 | 0.14 | 0.69 | 0.08 |
| | 1132 | 41.9 | 6.23 | 0.15 | 0.77 | 0.20 |
| | 1236 | | | | | |
| | 1345 | | | | | |

Alloy Production, Kg

| Shifts<br>Date | 12-8 | 8-4 | 4-12 | Days Total |
|---|---|---|---|---|
| 11/11/80 | 40,558 | 42,429 | 46,688 | 129,655 |
| 11/12/80 | 35,988 | 42,152 | 44,262 | 122,420 |
| 11/13/80 | 36,682 | 75,319 | -- | -- |

Assumed dry gas molecular weight are: scrubber outlet gas, 28.12; baghouse inlet, 28.84; baghouse outlet, 28.84. These assumptions have a slight effect on the calculated gas flow rates. The assumption of 80 percent CO in the scrubber outlet gas is equivalent to assuming little, if any, combustion of the gas under the furnace cover. Observations throughout the test substantiate the assumption. The cleaned gas is flared before release to the atmosphere.

### 9.4.2 Particulates

Given in Table 69 are results obtained for particulate matter in the scrubber outlet gas.

Particulate concentration in the gas for the one run made on 11/11/80 with furnace No.20 producing 65 percent FeSi was about 127 mg/dsm$^3$, yielding an emission rate of about 1.3 Kg/hour. In terms of operating parameters, particulate emissions were 0.03 Kg/MW-hr, 0.079 Kg/Mg raw material feed, and 0.246 Kg/Mg alloy produced. Scrubber pressure drops during the test were: north venturi, 98 mmHg (52.5 inches water); and south venturi, 127 mmHg (68 inches water). Visual observation of the furnace indicated significant amounts of fire on top of the furnace cover and probably heavy secondary fume generation. However, the amount of secondary fume generated was not quantified.

Particulate concentration in the scrubber outlet gas during the three runs made 11/13/80, when furnace No.20 was producing a 42 percent silicon, 6 percent Mn product, averaged about 266 mg/dsm$^3$, yielding an emission rate of about 2.4 Kg/hour. In terms of operating parameters, particulate emissions were 0.055 Kg/MW-hr, 0.121 Kg/Mg raw material fed, and 0.250 Kg/Mg alloy produced. There was very little variability in the results of the three runs. During these tests the scrubber pressure drops were about 150 mmHg (80 inches water) for both the north and south venturis.

Particulates in the baghouse inlet gas collected by the secondary hood above the furnace cover and the tap hood during Runs 4, 5, and 6 averaged about 502 mg/dsm$^3$ (see Table 70). These runs were made at the same time as

## TABLE 69. PARTICULATES, SCRUBBER OUTLET GAS

| Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Emitted per hour Kg | Average Load During Test MW-hr/hr | Emitted per MW-hr Kg | Emitted per Mg Feed Kg | Emitted per Mg Alloy Kg |
|---|---|---|---|---|---|---|---|
| 1 | 202.5 | 126.72 | 1.26 | 41.5 | 0.030 | 0.079 | 0.246 |
| 2 | 310.9 | 236.6 | 2.34 | 43.0 | 0.054 | 0.119 | 0.246 |
| 3 | 370.4 | 273.8 | 2.53 | 43.0 | 0.059 | 0.129 | 0.266 |
| 4 | 253.8 | 288.7 | 2.26 | 43.0 | 0.053 | 0.115 | 0.238 |
| Average Runs 2,3,4 | | 266.4 | 2.38 | 43.0 | 0.055 | 0.121 | 0.250 |

## TABLE 70. PARTICULATES, BAGHOUSE INLET GAS

| Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Generated per hour, Kg | Average Load During Test MW-hr/hr | Kg Generated MW-hr/hr | Kg Generated per Mg Feed | Kg Generated per Mg Alloy |
|---|---|---|---|---|---|---|---|
| 1 | 114.7 | 120.0 | 26.60 | 38 | 0.70 | 1.86 | 5.09 |
| 2 | 272.4 | 318.6 | 65.19 | 40 | 1.63 | 4.32 | 11.85 |
| 3 | 221.9 | 262 | 54.31 | 38.5 | 1.41 | 3.74 | 10.25 |
| 4 | 304.0 | 344.3 | 75.01 | 43 | 1.74 | 3.83 | 7.89 |
| 5 | 214.2 | 241.5 | 52.54 | 43 | 1.22 | 2.68 | 5.53 |
| 6 | 649.9 | 919.2 | 214.38 | 43 | 4.99 | 10.94 | 22.56 |
| Average Runs 1,2,3 |  | 233.5 | 48.7 | 38.8 | 1.25 | 3.31 | 9.06 |
| Average Runs 4,5,6 |  | 501.7 | 114.0 | 43 | 2.66 | 5.82 | 12.0 |

scrubber outlet Runs 2, 3, and 4. This corresponds to 114 Kg/hr of particulate going to the baghouse. In terms of operating parameters, particulate collected by the secondary fume system averaged about 2.7 Kg/MW-hr, 5.8 Kg/Mg raw material fed, and 12.0 Kg/Mg alloy produced. These results were strongly influenced by the high results obtained in Run No.6, which was over three times the average of Runs No.4 and 5. There is no obvious explanation for the variability observed. The process observer reported no unusual conditions at the furnace such as heavy fuming or fire on the furnace cover. Secondary fume capture was always greater than 90 percent. it appears, therefore, that this magnitude of variability is normal.

Given in Table 71 are the results for particulate captured by the scrubber taken at the same time as the scrubber outlet Runs 2, 3, and 4 and baghouse inlet Runs 4, 5, and 6. Run No.1 (for both scrubber outlet gas and discharged water) was made when the furnace was producing 65 percent ferrosilicon and is included for information only. The results are not included in the averages.

Particulate concentrations in the discharged water averaged about 1470 mg/L for Runs 2-4. Total particulate captured by the scrubber averaged about 190 Kg/operating hour. In terms of operating parameters, the average amount of particulate captured by the scrubber averaged 4.43 Kg/MW-hr, 9.74 Kg/Mg raw material feed, and 20.1 Kg/Mg alloy produced.

Given in Table 70 (Runs 1, 2, and 3) and Table 72 are the results of simultaneous testing in the baghouse inlet and outlet. For these runs, the average particulate concentration in the baghouse inlet, not including air drawn in from furnace 23, was about 234 mg/dsm$^3$, yielding 48.7 Kg/hr of particulate going to the baghouse. Particulate concentration in the baghouse outlet averaged 18.2 mg/dsm$^3$ or 11.7 Kg/hr emitted. Given in Table 73 are the calculated baghouse particulate collection efficiencies for these runs. This capture efficiency of 73.6 percent is very poor, however, the particulate concentration in the outlet is not high, which indicates the baghouse is operating reasonably well. We suspect the cause of the poor efficiency is that the actual inlet particulate concentration was much lower than the baghouse was designed to handle. The baghouse normally handles all

TABLE 71. PARTICULATES, SCRUBBER DISCHARGE WATER

| Run Number | Concentration[a] in water, mg/L | Captured[b] per hour, Kg | Average Load During Test MW-hr/hr | Captured per MW-hr, Kg | Captured per Mg Feed, Kg | Captured per Mg alloy, Kg |
|---|---|---|---|---|---|---|
| 1 | 2,724 | 353 | 41.5 | 8.51 | 22.2 | 69.0 |
| 2 | 1,004 | 130 | 43.0 | 3.02 | 6.63 | 13.7 |
| 3 | 1,580 | 205 | 43.0 | 4.77 | 10.5 | 21.6 |
| 4 | 1,828 | 237 | 43.0 | 5.51 | 12.1 | 24.9 |
| Average Runs 2, 3,4 | 1,471 | 191 | 43.0 | 4.43 | 9.74 | 20.1 |

[a] Corrected for solid concentration of 58.5 mg/L in scrubber feedwater.

[b] Scrubber discharge flow rate 2.16 $m^3$/min (570 gpm).

## TABLE 72. PARTICULATES, BAGHOUSE OUTLET

| Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Emitted per hour Kg | Average Load During Test Mw-hr/hr | Emitted per MW-hr Kg | Emitted per Mg Feed Kg | Emitted per Mg alloy Kg |
|---|---|---|---|---|---|---|---|
| 1 | 15.3 | 13.6 | 8.91 | 39.1 | 0.228 | 0.604 | 1.66 |
| 2 | 10.2 | 13.1 | 8.36 | 37.4 | 0.224 | 0.593 | 1.62 |
| 3 | 23.5 | 27.9 | 17.9 | 38.5 | 0.465 | 1.23 | 3.38 |
| Average |  | 18.2 | 11.7 | 38.3 | 0.306 | 0.809 | 2.22 |

TABLE 73. BAGHOUSE PARTICULATE CAPTURE EFFICIENCY

| Inlet Run Number | Outlet Run Number | Capture Efficiency, % |
|---|---|---|
| 1 | 1 | 66.5 |
| 2 | 2 | 87.2 |
| 3 | 3 | 67.0 |
| Overall Average | | 73.6 |

fume from furnace No.23. That furnace was not operating during the test but air was still being drawn through its hood at normal rates. Correcting the inlet particulate concentration for ambient air drawn in from furnace 23 gives an actual inlet particulate concentration to the baghouse of about 76 $mg/dsm^3$. Since the baghouse cleaning cycles were not different from normal operation with furnace 23 operating it is unlikely there was sufficient particulate in the inlet gas to form a dust cake on the bags between cleaning cycles. Without a dust cake, which serves as the major filter medium, capture efficiency would be poor. With both furnaces operating normally, the baghouse efficiency should be about 97 to 99 percent.

Given in Table 74 is a summary of all particulate test results obtained, with the exception of those made to determine baghouse efficiency, which were discussed above. Table 74 combines results given in the preceding four tables, as appropriate, to give a complete picture of particulate generated by and emitted from the furnace. The total amount of particulate generated by the furnace, which is the sum of the particulate in the scrubber discharge water, scrubber gas, and baghouse inlet gas collected by the hood above the furnace cover, averaged 307 Kg/operating hour. Of this, about 32.5 Kg/hour or 10 percent, was emitted to the atmosphere. This number was calculated using the measured baghouse collection efficiency of 73.6 percent and represents the actual emissions occurring during the test. Data presented in parentheses are based on assuming the baghouse would operate at 98 percent particulate collection efficiency if furnace No.23 were operating. The scrubber, which treats gas withdrawn from beneath the furnace cover, operated with an average particulate capture efficiency of 98.7 percent. In terms of operating parameters, the furnace generated a total of 7.14 Kg of particulate per MW-hr of furnace power. Of this 0.755 Kg/MW-hr was emitted to the atmosphere during the test. A total of 0.11 Kg/MW-hr would be emitted if the baghouse efficiency were 98 percent. The NSPS, which do not apply to the furnace, for particulate emissions is 0.23 Kg/MW-hr. Total particulate generated also averaged about 15.7 Kg/Mg of raw material fed and 32.3 Kg/Mg alloy produced. Total particulate emitted averaged 1.66 Kg/Mg raw material and 3.42 Kg/Mg alloy, which could be reduced to 0.24 and 0.49 Kg/Mg, respectively, if the baghouse efficiency were 98 percent.

TABLE 74. PARTICULATES, SUMMARY FURNACE 20

| Scrubber Run Number[a] | Generated per hour Kg | Emitted per hour Kg | Scrubber Efficiency % | Generated per MW-hr Kg | Emitted per MW-hr Kg | Generated per Mg Feed, Kg | Emitted per Mg Feed, Kg | Generated per Mg Alloy, Kg | Emitted per Mg Alloy, Kg |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 207.4 | 22.1<br>(3.8) | 98.2 | 4.81 | 0.513<br>(0.09) | 10.6 | 1.13<br>(0.20) | 21.8 | 2.33<br>(0.40) |
| 3 | 260.1 | 16.4<br>(3.6) | 98.8 | 6.05 | 0.381<br>(0.08) | 13.3 | 0.837<br>(0.18) | 27.4 | 1.73<br>(0.38) |
| 4 | 253.6 | 58.9<br>(6.5) | 99.1 | 10.55 | 1.37<br>(0.15) | 23.2 | 3.00<br>(0.33) | 47.7 | 6.19<br>(0.69) |
| Average Runs 2, 3,4 | 307.0 | 32.5<br>(4.6) | 98.7 | 7.14 | 0.755<br>(0.11) | 15.7 | 1.66<br>(0.24) | 32.3 | 3.42<br>(0.49) |

[a] Data given in columns headed "Generated" are the sum of results obtained for scrubber Runs No.2, 3, and 4 (scrubber outlet gas and discharge water) and baghouse inlet Runs No.4, 5, and 6. Columns headed "Emitted" contain the sum of results for scrubber outlet gas Runs No.2, 3, and 4 and baghouse inlet Runs No.4, 5, and 6. The numbers given reflect a baghouse efficiency of 73.6 percent. Numbers in parentheses reflect an assumed baghouse efficiency of 98 percent (assumed efficiency when the baghouse is operating at normal, full load-with furnace No.23 operating).

The scrubber captures slightly over 60 percent of all particulate generated by the furnace. About 37 percent of the particulate generated goes to the baghouse. Thus, it is obvious that the particulate collection efficiency of the baghouse is very important in determining overall emissions to the atmosphere. As explained previously, during the tests the particulate concentration and mass going to the baghouse was significantly less than normal because furnace No.23 was not operating. We believe this is the primary reason for the low (73.6 percent) measured baghouse efficiency. The baghouse itself is well maintained and operated and should perform as well as others tested in this project. Based on this rationale and previous observation by the same RTI observer as used for the current test of this baghouse operating under normal, full load conditions, we have included calculated emission rates assuming a baghouse collection efficiency of 98 percent. In our judgment, these calculated emission rates more accurately represent the actual emission rate for furnace No.20 when both furnaces No. 20 and 23 are operating normally.

Given in Tables 75 and 76 are the results of particle sizing runs made with an Andersen 2000 stack sampler on fume collected by the secondary hood above the furnace cover. The results given in Table 75 were taken late in the afternoon of 11/12/80, the day the furnace was being switched over from 65 to 50 percent ferrosilicon. The alloy being tapped analyzed 50 percent ferrosilicon for each of the three taps preceding the test, or for about 5 hours before the test. The furnace was not being tapped during the test. As can be seen from the table, only about 14 percent of the particulate mass had mean aerodynamic diameters of 8.0 μm or less. The results given in Table 76 were obtained on 11/13/80, while the furnace product was about 42 percent silicon, 6 percent manganese, 50 percent iron. Alloy analysis had been consistent for at least four taps, or at least 5 1/2 hours. The furnace was being tapped during the test. As can be seen from the table, over 39 percent of the particulate mass had mean aerodynamic diameters of 7.6 μm or less.

It is highly unlikely that the difference in alloy being produced could be responsible for the difference in particle size found. The difference in mean diameter found is likely due to inclusion of tap fume in the run made on 11/13/80, however, it may simply reflect short-term process fluctuations.

TABLE 75. PARTICLE SIZING DATA

Plant: Union Carbide Corporation, Metals Division, Ashtabula, Ohio

Sampling Location: Baghouse Inlet; Furnace No.20 Date: 11/12/80

| | | | |
|---|---|---|---|
| Start Time: | 1615 | Finish Time: | 1630 |
| Barometer Pressure, cm Hg: | 74.68 | Sampling Time, minutes: | 15 |
| Static Pressure, mm Hg | -4.7 | Volume Metered, A $m^3$: | 0.2352 |
| Stack Gas Temperature, °C: | 46.1 | Meter Calibration Factor: | 1.001 |
| % Moisture by Volume: | 1.0 | Meter Temperature, °C: | 19 |
| Viscosity Correlation Factor: | 1.040 | Delta H Average, mm Hg: | 1.8 |
| Density Correlation Factor: | 1.000 | Particle Density, gm/cc: | 1.00 |

A $m^3$/min Flow Rate through Nozzle: 0.0175

| Stage Number | Particle Diameter (microns) From Graph | Particle Diameter (microns) Aerodynamic | Catch Weight (mg) | Percent of Total (%) | Cumulative % Less Than Given Diameter |
|---|---|---|---|---|---|
| 0 | 12.27 | 12.76 | 163.1 | 83.8 | 16.2 |
| 1 | 7.69 | 8.00 | 3.8 | 2.0 | 14.2 |
| 2 | 5.14 | 5.34 | 3.9 | 2.0 | 12.2 |
| 3 | 3.56 | 3.70 | 3.2 | 1.6 | 10.6 |
| 4 | 2.25 | 2.34 | 2.8 | 1.4 | 9.1 |
| 5 | 1.15 | 1.20 | 4.1 | 2.1 | 7.0 |
| 6 | 0.70 | 0.73 | 5.1 | 2.6 | 4.4 |
| 7 | 0.48 | 0.50 | 3.7 | 1.9 | 2.5 |
| Filter | < 0.48 | < 0.50 | 4.9 | 2.5 | |
| Total Catch | | | 194.6 | | |

## TABLE 76. PARTICLE SIZING DATA

Plant: Union Carbide Corporation, Metals Division, Ashtabula, Ohio

Sampling Location: Baghouse Inlet; Furnace No.20 Date: 11/13/80

| | | | |
|---|---|---|---|
| Start Time: | 1340 | Finish Time: | 1347 |
| Barometer Pressure, cm Hg: | 73.91 | Sampling Time, minutes: | 7.0 |
| Static Pressure, mm Hg: | -4.7 | Volume Metered, A $m^3$: | 0.1198 |
| Stack Gas Temperature, °C: | 63.9 | Meter Calibrated Factor: | 1.001 |
| % Moisture by Volume: | 1.0 | Meter Temperature, °C: | 21 |
| Viscosity Correlation Factor: | 1.060 | Delta H Average, mm Hg: | 2.15 |
| Density Correlation Factor: | 1.000 | Particle Density, gm/cc: | 1.00 |
| A $m^3$/min Flow Rate through Nozzle: | 0.0199 | | |

| Stage Number | Particle Diameter (microns) From Graph | Particle Diameter (microns) Aerodynamic | Catch Weight (mg) | Percent of Total (%) | Cumulative % Less Than Given Diameter |
|---|---|---|---|---|---|
| 0 | 11.44 | 12.13 | 29.3 | 57.9 | 42.1 |
| 1 | 7.18 | 7.61 | 1.4 | 2.8 | 39.3 |
| 2 | 4.79 | 5.08 | 1.6 | 3.2 | 36.2 |
| 3 | 3.32 | 3.52 | 1.3 | 2.6 | 33.6 |
| 4 | 2.10 | 2.22 | 1.3 | 2.6 | 31.0 |
| 5 | 1.07 | 1.14 | 3.3 | 6.5 | 24.5 |
| 6 | 0.65 | 0.69 | 4.2 | 8.3 | 16.2 |
| 7 | 0.44 | 0.47 | 4.1 | 8.1 | 8.1 |
| Filter | < 0.44 | < 0.47 | 4.1 | 8.1 | |
| Total Catch | | | 50.6 | | |

### 9.4.3 Organics

Given in Table 77 are the results obtained for organics in the scrubber discharge water. The results from Run No.1 are not included in this discussion. Organic concentration in the water averaged 324 mg/L, with a range of 281 to 375 mg/L. About 95 percent of the organic matter was adsorbed on the suspended solids. Total organics captured by the scrubber averaged 42 Kg/hr or about 22 percent as much as the particulate matter captured. In terms of operating parameters, the scrubber captured about 1 Kg organic per MW-hr, 2.1 Kg/Mg raw material fed, and 4.4 Kg/Mg alloy tapped.

Given in Table 78 are the results for organics in the outlet gas from the scrubber. Excluding the results of Run No.1, organic concentration in the gas averaged 682 mg/dsm$^3$, with a range of 217 to 1020 mg/dsm$^3$. The analytical method used does not measure low boiling point organic. Thus, these numbers do not include any contribution from the kerosene injected into the gas stream at the exhaust fans. Total organics in the gas discharged by the scrubber and going to the flare was 5.8 Kg/operating hour or about 2.5 times as much as the particulate matter found at this location. About 22 percent of the organic was adsorbed on the particulate matter, however, this number may be low since the sampling train filter was maintained at 121°C, considerably hotter than the stack gas temperature of about 86°C. In terms of operating parameters, organic contained in the gas discharged by the scrubber averaged 0.14 Kg/MW-hr, 0.30 Kg/Mg raw material fed, and 0.61 Kg/Mg alloy tapped.

Comparing data on the scrubber discharge water and gas discharged from the scrubber, the scrubber captured about 88.5 percent of the organic in the incoming gas.

It should be clearly understood that results presented for the scrubber discharge gas are before the gas is flared. Significant destruction of organics is expected to occur in the flare.

Given in Table 79 are the organic results obtained for secondary fumes from the furnace cover going to the baghouse. Runs 1, 2, and 3 were made the day the furnace was being switched from 65 percent to 50 percent FeSi. Runs

## TABLE 77. ORGANIC, SCRUBBER DISCHARGE WATER

| Run Number | Concentration[a] mg/L | Captured per hour, Kg | Captured per MW-hr, Kg | Captured per Mg Feed, Kg | Captured per Mg Alloy, Kg |
|---|---|---|---|---|---|
| 1 | 505.3 | 65.49 | 1.58 | 4.12 | 12.8 |
| 2 | 281.2 | 36.44 | 0.847 | 1.86 | 3.83 |
| 3 | 316.7 | 41.04 | 0.954 | 2.09 | 4.32 |
| 4 | 374.6 | 48.55 | 1.13 | 2.48 | 5.11 |
| Average runs 2, 3, & 4 | 324.2 | 42.01 | 0.977 | 2.14 | 4.42 |

[a] Corrected for 29.8 mg/L organic in scrubber feedwater.

TABLE 78. ORGANICS, SCRUBBER OUTLET GAS

| Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Emitted[a] per hour, Kg | Emitted per MW-hr, Kg | Emitted per Mg Feed, Kg | Emitted per Mg Alloy, Kg |
|---|---|---|---|---|---|---|
| 1 | 1065 | 666.5 | 6.63 | 0.160 | 0.418 | 1.30 |
| 2 | 285 | 217 | 1.91 | 0.0444 | 0.0974 | 0.201 |
| 3 | 1100 | 813 | 7.50 | 0.174 | 0.383 | 0.789 |
| 4 | 894 | 1017 | 7.97 | 0.185 | 0.406 | 0.838 |
| Average runs 2,3, & 4 |  | 682 | 5.79 | 0.135 | 0.295 | 0.609 |

[a] Emitted used here refers to organics going to the flare. Significant destruction of organics in the flare is expected.

TABLE 79. ORGANICS, BAGHOUSE INLET

| Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Generated per hour, Kg | Generated per MW-hr, Kg | Generated per Mg Feed, Kg | Generated per Mg Alloy, Kg |
|---|---|---|---|---|---|---|
| 1 | 49 | 51.26 | 11.36 | 0.299 | 0.793 | 2.17 |
| 2 | 32 | 37.43 | 7.66 | 0.192 | 0.508 | 1.39 |
| 3 | 35 | 41.32 | 8.57 | 0.223 | 0.590 | 1.62 |
| 4 | 100 | 113.3 | 24.67 | 0.574 | 1.26 | 2.60 |
| 5 | 102 | 115.0 | 25.02 | 0.582 | 1.28 | 2.63 |
| 6 | 61 | 86.28 | 20.12 | 0.468 | 1.03 | 2.12 |
| Average runs 1, 2, & 3 | | 43.3 | 9.20 | 0.24 | 0.63 | 1.73 |
| Average runs 4, 5, & 6 | | 104.9 | 23.27 | 0.54 | 1.19 | 2.45 |

4, 5, and 6 were made the following day when the furnace was producing 42 percent FeSi, 6 percent Mn.

For the first three runs, which were made to determine baghouse capture efficiency and correspond to outlet runs 1, 2, and 3 in Table 80, the organic concentration in the gas averaged 43 mg/dsm$^3$ giving an organic generation rate of 9.2 Kg/operating hour. This is about 19 percent of the particulate generation rate for these tests. About 52 percent of the organic was adsorbed on the particulate matter, however, this number may be low since the gas temperature was about 70°C, significantly less than the sampling train filter temperature of 121°C. In terms of operating parameters, these runs averaged 0.24 Kg organic/MW-hr, 0.63 Kg/Mg raw material fed, and 1.7 Kg/Mg alloy produced.

The last three baghouse inlet runs (4, 5, 6) were made simultaneously with scrubber testing Runs 2-4 to determine totals generated by the furnace. No baghouse outlet runs were made concurrently with these tests. For these three tests, the organic concentration in the gas averaged 105 mg/dsm$^3$, with a range of 86 to 115 mg/dsm$^3$. The organic generation rate determined was 23.3 Kg/operating hour. This is about 20 percent of the particulate generation rate. About 13 percent of the organic was adsorbed on the particulate matter. Again, this number may be low since the gas temperature was about 56°C, significantly less than the 121°C at which the sampling train filter was maintained. In terms of operating parameters, the runs averaged 0.54 Kg organic per MW-hr, 1.2 Kg/Mg raw material fed, and 2.5 Kg/Mg alloy tapped.

Given in Table 80 are the results obtained for organic in the baghouse outlet. These data correspond to inlet runs 1, 2, and 3, Table 79. For the three runs, the organic concentration averaged about 36 mg/dsm$^3$, with a range of 12.5 to 84 mg/dsm$^3$. This corresponds to an average emission rate of 23.5 Kg/operating hour. Note, however, that run No.3 appears to definitely be out of line. Run No.3 also appears to be in serious error when compared to the inlet organic loading, indicating over 6 times as much emitted as entering the baghouse. Similar results were found for at least one run at all other baghouses tested. Possible reasons for this have been discussed. Averages for runs No.1 and 2 are also given in the table. For

TABLE 80. ORGANICS, BAGHOUSE OUTLET

| Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Emitted per hour, Kg | Emitted per MW-hr, Kg | Emitted per Mg Feed, Kg | Emitted per Mg Alloy, Kg |
|---|---|---|---|---|---|---|
| 1 | 14 | 12.47 | 8.17 | 0.209 | 0.554 | 1.52 |
| 2 | 10 | 12.80 | 8.17 | 0.218 | 0.579 | 1.59 |
| 3 | 71 | 84.42 | 54.1 | 1.405 | 3.73 | 10.2 |
| Average, all runs |  | 35.6 | 23.5 | 0.61 | 1.62 | 4.44 |
| Average runs 2 & 3 |  | 12.6 | 8.17 | 0.214 | 0.566 | 1.56 |

runs 1 and 2, 45 percent of the organic was adsorbed on the particulate emitted, 28 percent in run No.3. Also organic emissions were about 95 percent as great as the particulate emission for these runs.

Given in Table 81 is a summary of the preceding tables for organics from this furnace. In this table, the amounts generated are the sum of organics in the scrubber discharge water, scrubber outlet gas, and baghouse inlet (runs 4, 5, 6). The amounts emitted are calculated two ways.

The first number given assumes no destruction of organic in the scrubber outlet gas by the flare. This would be valid only when the flare is not operating. In addition, the assumption has been made that the baghouse collection efficiency for organics, 13 percent, is the same as the percent organic found on the baghouse inlet particulate matter in runs 4, 5, and 6. While this percent capture might be low for the low baghouse temperature during the test, it is likely correct, or nearly so, for the normal baghouse temperature which is as high or higher than the sampling train filter (121°C). This efficiency is also quite similar to the 10.7 percent average capture efficiency measured in baghouse runs 1 and 2.

The second number given in the "Emitted" columns assumes 100 percent of the organic in the scrubber outlet gas is destroyed in the flare and makes the same assumption as above for organic capture by the baghouse.

The furnace generated about 71 Kg organic/operating hour. Of this, about 20 Kg/hr or about 28 percent was probably emitted. All of this would be from the secondary fume control system. In terms of operating parameters, the furnace generated 1.65 Kg/MW-hr and emitted about 0.5 Kg/MW-hr, generated 3.6 Kg/Mg raw material fed and emitted about 1 Kg/Mg feed, generated 7.5 Kg/Mg alloy tapped and emitted 2.1 Kg/Mg alloy.

Comparing this to data in the summary table (Table 74) for particulates, the furnace generates about 23 percent as much organic matter as particulate matter. Organic emissions are slightly less than or significantly greater (factor of 4) than the particulate emissions, depending on the baghouse particulate capture efficiency assumption to which organics are compared.

TABLE 81. SUMMARY, ORGANICS - FURNACE NO.20

| Run Number | Generated per hour Kg | Emitted per hour Kg | Scrubber Efficiency % | Generated per MW-hr Kg | Emitted per MW-hr Kg | Generated per Mg Feed Kg | Emitted per Mg Feed, Kg | Generated per Mg Alloy, Kg | Emitted per Mg Alloy, Kg |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 63.02 | 23.37[a] | 95.0 | 1.47 | 0.543 | 3.22 | 1.19 | 6.63 | 2.46 |
| | | 21.46[b] | | | 0.499 | | 1.10 | | 2.26 |
| 3 | 73.56 | 29.27 | 84.5 | 1.71 | 0.68 | 3.75 | 1.49 | 7.74 | 3.08 |
| | | 21.77 | | | 0.506 | | 1.11 | | 2.29 |
| 4 | 76.64 | 25.47 | 85.9 | 1.78 | 0.592 | 3.92 | 1.30 | 8.07 | 2.68 |
| | | 17.50 | | | 0.407 | | 0.90 | | 1.84 |
| Average | 71.1 | 26.0 | 88.5 | 1.65 | 0.60 | 3.63 | 1.33 | 7.48 | 2.74 |
| | | 20.2 | | | 0.47 | | 1.04 | | 2.13 |

[a] No credit for flare destruction of organic and 13% organic capture by baghouse.

[b] Assumes 100% destruction of organic in scrubber outlet gas by flaring and 13% organic capture by baghouse.

### 9.4.4 Benzo(a)Pyrene

Given in Table 82 are the results obtained for BaP in the scrubber discharge water. The average BaP concentration for runs 2, 3, and 4 was 1.33 mg/L, with a range of 1.02 to 1.76 mg/L. Total BaP captured by the scrubber averaged 173 grams per hour or 0.4 percent of the organic matter found. Over 99.9 percent of the BaP was adsorbed on the particulate matter. BaP content of the suspended solids discharged by the scrubber is, therefore, about 910 μg/gram. In terms of operating parameters, the scrubber captured 4 grams BaP/MW-hr, 8.8 grams/Mg raw material fed, and 18 grams/Mg alloy tapped.

Given in Table 83 are the results for BaP in the scrubber outlet gas. The BaP concentration averaged, for runs 2, 3, and 4, 86 $\mu g/dsm^3$, with a range of 66 of 123 $\mu g/dsm^3$. The total BaP in the gas discharged by the scrubber and going to the flare averaged 0.72 grams per operating hour or about 0.12 percent of the organic matter at this location. About 65 percent of the BaP was adsorbed on the particulate matter. In terms of operating parameters, BaP in the gas discharged to the flare by the scrubber averaged 0.017 g/MW-hr, 0.037 g/Mg raw material fed, and 0.076 g/Mg alloy tapped. The scrubber captured about 82 percent of the incoming BaP.

Given in Table 84 are the results for BaP in the secondary fume entering the baghouse. For the first three runs the BaP concentration in the gas was 7.8 $\mu g/dsm^3$, with a range of 6.4 to 8.7 $\mu g/dsm^3$. The BaP generation rate from this source was about 1.7 grams/hour. This is about $1.8 \times 10^{-2}$ percent of the organic matter found in these tests. About 90 percent of the BaP was adsorbed on the particulate matter.

For the second three runs (4, 5, 6), which were made when the furnace was producing 42 percent FeSi, the BaP concentration in the gas averaged 5.3 $\mu g/dsm^3$, with a range of 2.5 to 7.7 $\mu g/dsm^3$. The BaP generation rate was about 1.2 grams/hour. This is about $5 \times 10^{-3}$ percent of the organic matter found in these tests. About 80 percent of the BaP was adsorbed on the particulate.

Given in Table 85 are the results for BaP in the baghouse outlet gas. These samples were taken simultaneously with baghouse inlet runs 1, 2, and 3. The average BaP concentration in the gas was about 0.9 $\mu g/dsm^3$. This

TABLE 82. BaP, SCRUBBER DISCHARGE WATER

| Run Number | Concentration in Water[a] μg/L | Captured per hour, gms | Captured per MW-hr, gms | Captured per Mg Feed, gms | Captured per Mg Alloy, gms |
|---|---|---|---|---|---|
| 1 | 754 | 97.7 | 2.35 | 6.15 | 19.1 |
| 2 | 1219 | 158 | 3.67 | 8.06 | 16.63 |
| 3 | 1019 | 132 | 3.07 | 6.73 | 13.89 |
| 4 | 1764 | 229 | 5.32 | 11.68 | 24.1 |
| Average runs 3, 3, & 4 | 1334 | 173 | 4.02 | 8.82 | 18.2 |

[a] Corrected for BaP concentration in scrubber feedwater of 15.4 μg/L.

TABLE 83. BaP, SCRUBBER OUTLET GAS

| Run Number | μg Captured | Concentration in Gas, $\mu g/dsm^3$ | Emitted[a] per hour, gms | Emitted Per MW-hr, gms | Emitted per Mg Feed, gms | Emitted per Mg Alloy, gms |
|---|---|---|---|---|---|---|
| 1 | 82 | 51 | 0.51 | 0.012 | 0.032 | 0.10 |
| 2 | 90 | 68 | 0.60 | 0.014 | 0.031 | 0.063 |
| 3 | 89 | 66 | 0.61 | 0.014 | 0.031 | 0.064 |
| 4 | 108 | 123 | 0.96 | 0.022 | 0.049 | 0.10 |
| Average runs 2, 3, & 4 | | 86 | 0.72 | 0.017 | 0.037 | 0.076 |

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[a] Emitted as used here refers to BaP going to the flare. Significant destruction of BaP in the flare is expected.

TABLE 84. BaP, BAGHOUSE INLET GAS

| Run Number | μg Captured | Concentration in Gas, μg/dsm$^3$ | Generated per hour, gms | Generated per MW-hr, gms | Generated per Mg Feed, gms | Generated per Mg Alloy, gms |
|---|---|---|---|---|---|---|
| 1 | 8.0 | 8.4 | 1.86 | 0.049 | 0.13 | 0.36 |
| 2 | 5.5 | 6.4 | 1.31 | 0.033 | 0.087 | 0.24 |
| 3 | 7.4 | 8.7 | 1.80 | 0.047 | 0.12 | 0.34 |
| 4 | 6.8 | 7.7 | 1.68 | 0.039 | 0.086 | 0.18 |
| 5 | 5.1 | 5.7 | 1.24 | 0.029 | 0.063 | 0.13 |
| 6 | 1.8 | 2.5 | 0.583 | 0.014 | 0.030 | 0.061 |
| Average runs 1, 2, & 3 |  | 7.8 | 1.66 | 0.043 | 0.11 | 0.31 |
| Average runs 4, 5, & 6 |  | 5.3 | 1.17 | 0.027 | 0.060 | 0.12 |

## TABLE 85. BaP, BAGHOUSE OUTLET

| Run Number | μg Captured | Concentration in Gas, μg/dsm$^3$ | Emitted per hour, gms | Emitted per MW-hr, gms | Emitted per Mg Feed, gms | Emitted per Mg Alloy, gms |
|---|---|---|---|---|---|---|
| 1 | 0.8 | 0.71 | 0.47 | 0.012 | 0.032 | 0.087 |
| 2 | 0.8 | 1.0 | 0.64 | 0.017 | 0.045 | 0.12 |
| 3 | 0.8 | 0.95 | 0.61 | 0.016 | 0.042 | 0.12 |
| Average |  | 0.88 | 0.57 | 0.015 | 0.040 | 0.11 |

corresponds to an average emission of 0.57 grams/hour. This is roughly 7 x $10^{-3}$ percent of the organic matter. All BaP detected was adsorbed on the particulate matter.

Given in Table 86 are the calculated baghouse capture efficiencies for BAP. With the exception of run No.2, these results are quite similar to the particulate capture efficiency.

TABLE 86. BAGHOUSE BaP COLLECTION EFFICIENCY

| Inlet Run Number | Outlet Run Number | Capture Efficiency, % |
|---|---|---|
| 1 | 1 | 74.7 |
| 2 | 2 | 51.1 |
| 3 | 3 | 66.1 |
| Overall Average | | 64.0 |

Given in Table 87 is a summary of data presented in the preceding tables detailing BaP results for the furnace. Data in columns headed "Generated" sum the BaP content in the scrubber discharge water and the cleaned gas going to the flare during scrubber runs 2, 3, and 4 and baghouse inlet runs 4, 5, and 6. Data in columns headed "Emitted" are calculated three ways as follows:

1. The first number assumes no destruction of BaP by the flare. The assumption is valid only when the flare is not operating. Additionally it is assumed that the BaP capture by the baghouse is the same as measured for particulates. We believe this assumption to be valid. (See Tables 73 and 86).
2. The second number also assumes no destruction for the BaP in the scrubber outlet gas. It also assumes 79 percent capture of BaP by the baghouse. This is the estimated BaP capture when the baghouse is operating under normal full load conditions. Justification for this assumption is that 79 percent of the BaP in inlet runs 4, 5, and 6 was adsorbed on the particulate when the sampling train filter system was maintained at 121°C, which is the approximate normal temperature of the baghouse. It is quite possible that the BaP capture efficiency would be less than this if the baghouse temperature were much above 121°C.

## TABLE 87. BaP, SUMMARY FURNACE 20

| Run Number | Generated per hour gms | Emitted per hour gms | Scrubber Efficiency % | Generated per MW-hr gms | Emitted per MW-hr gms | Generated per Mg Feed gms | Emitted per Mg gms | Generated per Mg gms | Emitted per Mg gms |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 160.3 | 1.0[a] | 99.6 | 3.72 | 0.024 | 8.18 | 0.054 | 16.9 | 0.11 |
| | | 0.95[b] | | | 0.022 | | 0.049 | | 0.10 |
| | | 0.35[c] | | | 0.008 | | 0.018 | | 0.038 |
| 3 | 133.9 | 0.94 | 99.5 | 3.11 | 0.022 | 6.82 | 0.048 | 14.1 | 0.098 |
| | | 0.87 | | | 0.02 | | 0.044 | | 0.091 |
| | | 0.26 | | | 0.006 | | 0.013 | | 0.038 |
| 4 | 230.5 | 1.1 | 99.6 | 5.36 | 0.026 | 11.76 | 0.057 | 24.3 | 0.12 |
| | | 1.1 | | | 0.025 | | 0.055 | | 0.11 |
| | | 0.12 | | | 0.003 | | 0.006 | | 0.013 |
| Average | 174.9 | 1.01 | 99.6 | 4.06 | 0.024 | 8.92 | 0.053 | 18.4 | 0.11 |
| | | 0.97 | | | 0.022 | | 0.049 | | 0.10 |
| | | 0.24 | | | 0.006 | | 0.012 | | 0.030 |

[a] No credit for flare and 73.6% baghouse efficiency.

[b] No credit for flare and 79% baghouse efficiency.

[c] 100% credit for flare and 79% baghouse efficiency.

3. The third number assumes 100 percent BaP destruction by the flare and 79 percent BaP capture by the baghouse. We believe this most nearly represents normal operations at the plant for this furnace. (Of course, under normal operations, furnace No.23 could contribute to BaP emissions from the baghouse).

The total amount of BaP generated by the furnace averaged about 175 grams/hour, with a range of 134 to 230 grams/hour. Total emission from the furnace control systems was 1.0, 0.97, and 0.24 grams/hour for calculation methods 1, 2, and 3, respectively. Thus, BaP capture efficiency averaged 99.4, 99.4, and 99.9 percent for calculation Method 1, 2, and 3, respectively. In terms of operating parameters, the furnace generated about 4 grams BaP/MW-hr and would potentially emit about 6 x $10^{-3}$ grams/MW-hr under normal flare and baghouse operating conditions; generated about 4 grams BaP/MW-hr and would potentially emit about 6 x $10^{-3}$ grams/MW-hr under normal flare and baghouse operating conditions; generated about 8.9 grams per Mg raw material fed and would potentially emit 1.2 x $10^{-2}$ grams/Mg feed; generated about 18.4 grams per Mg alloy tapped and would potentially emit 3 x $10^{-2}$ grams/Mg alloy tapped.

### 9.4.5 GC-MS Analysis of Baghouse Emissions

The sample extracts of all baghouse outlet runs were combined for a single GC-MS analysis. The samples were composited as follows. There are two samples from each of the three runs: (1) combined probe wash and filter extract; and (2) XAD-2 resin extract. The original volume of each extract was 10.0 mL. One (1.0 ml) of each extract (6.0 mL total), 10 percent of the extract, was transferred to a single vial. This composite sample was sent to Stewart Laboratories for analysis. Their results, ng/μL, are reported in Appendix D. Thus, their results should be multiplied by 60 to get the mg in the total original extracts.

The results of the analysis are given in Table 88. Concentration in the gas was calculated by dividing the total g by the total gas volume collected in the runs. The amount emitted was calculated using the average baghouse outlet flow rate.

## TABLE 88. GC-MS ANALYSIS OF BAGHOUSE EMISSION SAMPLES, COVERED 50% FERROSILICON FURNACE

| Component | Total[a] in Samples µg | Concentration in Gas, µg/m$^3$ | Emitted per hour grams |
|---|---|---|---|
| Naphthalene | 1,190 | 433 | 279 |
| Biphenyl | 100 | 37 | 24 |
| Fluorene[b] | 20 | 9 | 6 |
| Anthracene | 160 | 57 | 37 |
| Methylanthracene[b] | 6 | 2 | 1 |
| Phenylnaphthalene | 50 | 20 | 10 |
| Fluoranthene[b] | 40 | 20 | 10 |
| Pyrene[b] | 20 | 9 | 6 |
| Chrysene[b] | 6 | 2 | 1 |
| Total: | 1,592 | 589 | 374 |

[a] All samples from the baghouse outlet runs were combined for a single analysis.

[b] Quantitative suspect due to low level of compound in sample analyzed.

Five of the compounds identified were present in such low concentrations that quantitation was difficult. Thus, these concentrations should be considered estimates only.

Only one known carcinogen, chrysene, was found, and then at low concentration. The GC-MS did not show evidence of BaP. This is contrary to results obtained in the RTI laboratory. It is quite possible, considering the sample splitting and low BaP concentration, that BaP was below the GC- MS detection limit. (For estimate see Table 35.) The sum of all identified polynuclear aromatics is about 0.6 mg/m$^3$.

Note that biphenyl was identified in these samples. It was also present in emissions from the silicon metal furnace. Since this compound has a boiling point over 250°C, this suggests that biphenyl may be present on the baghouse dust which is slurried and discharged to the wastewater treatment ponds. If this is the case, some, or all, of the PCB found in the treated effluent could have come from chlorination of this compound rather than from chlorination of PCB in the plant intake water.

## 9.5 WASTEWATER TREATMENT

A schematic of the wastewater treatment area was shown in Figure 12. Scrubber water from furnace 20 is discharged to Pond 4B after passing through a clarifier. Solids collected by the baghouse are slurried and also discharged to this pond. Solids collected from the calcium carbide, alloy crushing, coke drying, and lime calcining operations (scrubber water, etc.) are discharged into pond 4A. Solids settle out in these ponds and the partially clarified water passes into pond 4C where it is chlorinated. The chlorinated water passes through pond 4D before being discharged to Lake Erie.

An 8 liter (2 gallon) sample was collected of pond D outlet water between 10:48 a.m. and 3:50 p.m. on 11/11/81 using an automatic compositing water sampler. Discharge flow rate was 4.92 m$^3$/min (1300 gpm), as read from the plant wastewater discharge flow meter.

An 8-liter sample was collected, using the same sampler, of the influent to ponds 4A and 4B (4 liters each) between 9:00 a.m. and 2:30 p.m. on 11/13/80. The plant wastewater discharge flow meter indicated a flow rate of 4.92 m$^3$/min (1300 gpm) when the sample was taken. Estimated flow rate into the ponds is 2.0 $m^3$/min (530 gpm) for pond 4B and 3.3 $m^3$/min (880 gpm) for pond 4A. These estimates are based on pipe diameters and point of entry into the pond when the pipe was held horizontal, using the method given in Reference 9. The samples were homogenized and split in the RTI laboratory. One portion of the sample was filtered for suspended solids determination and the filtrate and solids further analyzed by RTI for organics and BaP. A second portion of the sample was analyzed for EPA designated priority pollutants by Stewart Laboratories, Inc. A third portion was used for tests discussed in the following section on solid wastes.

Given in Table 89 are the suspended solids, organic, and BaP data for the Ashtabula plant wastewater treatment pond system. The suspended solids concentration in the composite pond inlet water sample was slightly over 4000 mg/L. Total solids discharged to the pond in a 24 hour period was calculated to be about 28,850 Kg, using the outlet flow rate from pond 4D. The concentration of total organic matter in the influent was about 210 mg/L (1490 Kg/day). Of this, 17.5 mg/L was dissolved in the water and 193 mg/L was adsorbed on the suspended solids. The organic content of the solids was, therefore, 4.7 percent.

A total of 396 μg/L of BaP (2.8 Kg/day) was found in the portion of the sample analyzed by RTI (note that this differs from the value obtained from Stewart Laboratories, Inc. on what should have been an identical sample). All of the BaP was adsorbed on the suspended solids. BaP, therefore, constituted 0.19 percent of the total organic matter, 0.2 percent of the organic adsorbed on the solids, and 0.01 percent of the solids.

The water discharged from the treatment system contained no detectable BaP, no supsended solids, and only 1 mg/L organic matter. The combination of solids settling and removal followed by chlorination resulted, therefore, in a dramatic improvement in water quality. Removal of suspended solids results in a 92 percent decrease in total organics and a 100 percent reduction in BaP.

Both samples were also analyzed for priority pollutants. The results of these analyses are given in Tables 90-94. The pond inlet sample contained several carcinogenic polynuclear aromatic (PNA) compounds (benz(a)anthracene,

TABLE 89. TSS, ORGANIC, AND BaP IN ASHTABULA PLANT WASTEWATER

| Component | Concentration in Sample | Entering Pond[a] per 24 hours, Kg |
|---|---|---|
| A. Wastewater Pond Inlet | | |
| Suspended Solids | 4,070 mg/L | 28,850 |
| Organics | | |
| Dissolved in Water | 17.5 mg/L | 124 |
| Adsorbed on Solids | 193.2 mg/L | 1,370 |
| Total | 210.7 mg/L | 1,490 |
| BaP | | |
| Dissolved in Water | ND μg/L | 0 |
| Adsorbed on Solids | 396 μg/L | 2.8 |
| Total | 396 μg/L | 2.8 |
| | | Discharged from Pond[a] per 24 hours |
| B. Wastewater Pond Outlet | | |
| Suspended Solids | ND[b] mg/L | 0 |
| Organics, Total (all dissolved in water) | 1.0 mg/L | 7.1 |
| BaP, Total | ND μg/L | 0 |

[a] Based on pond outlet flow rate of 4.29 $m^3$/min (1300 gpm).

[b] Below detection limits of: TSS, 0.05 mg/L; BaP, 0.25 μg/L.

TABLE 90. VOLATILE ORGANIC PRIORITY POLLUTANT ANALYSIS

| Compound | Ponds A & B Inlet Concentration µg/L | Pond D Outlet Concentration µg/L |
|---|---|---|
| benzene | 460 | 21 |
| bromomethane | ND | ND |
| bromodichloromethane | ND | <10 |
| dibromochloromethane | ND | ND |
| bromoform | ND | ND |
| carbon tetrachloride | ND | ND |
| chlorobenzene | ND | ND |
| chloroethane | ND | ND |
| 1,1-dichloroethane | ND | ND |
| 1,2-dichloroethane | ND | ND |
| 1,1,1-trichloroethane | ND | ND |
| 1,1,2-trichloroethane | ND | ND |
| 1,1,2,2-tetrachloroethane | ND | ND |
| 1,1-dichloroethylene | ND | ND |
| trans-1,2-dichloroethylene | ND | ND |
| trichloroethylene | ND | ND |
| 1,1,2,2-tetrachloroethylene | ND | ND |
| 2-chloroethyl vinyl ether | ND | ND |
| chloroform | <10 | 70 |
| chloromethane | ND | ND |
| dichlorodifluoromethane | ND | ND |
| trichlorofluoromethane | ND | ND |
| ethyl benzene | 10 | <10 |
| methylene chloride | 27 | 18 |
| 1,2-dichloropropane | ND | ND |
| 1,3-dichloropropene | ND | ND |
| toluene | 250 | 11 |
| vinyl chloride | ND | ND |
| acrolein | ND | ND |
| acrylonitrile | ND | ND |

ND = Not Detected.
<10 µg/L = Detected but at a level less than 10 µg/L.

## TABLE 91. BASE-NEUTRAL EXTRACTABLE ORGANICS - PRIORITY POLLUTANT ANALYSIS

| Compound | Ponds A & B Inlet Concentration µg/L | Pond D Outlet Concentration µg/L |
|---|---|---|
| 1,3-dichlorobenzene | ND | ND |
| 1,4-dichlorobenzene | ND | ND |
| hexachloroethane | ND | ND |
| 1,2-dichlorobenzene | ND | ND |
| bis(2-chloroisopropyl)ether | ND | ND |
| hexachlorobutadiene | ND | ND |
| 1,2,4-trichlorobenzene | ND | ND |
| naphthalene | 1200 | <10 |
| bis(2-chloroethyl)ether | ND | ND |
| hexachlorocyclopentadiene | ND | ND |
| nitrobenzene | ND | ND |
| bis(2-chloroethoxy)methane | ND | ND |
| 2-chloronaphthalene | ND | <10 |
| acenaphtylene | 990 | <10 |
| acenaphthene | 25 | <10 |
| isophorone | ND | ND |
| fluorene | 280 | <10 |
| 2,6-dinitrotoluene | ND | ND |
| 1,2-diphenylhydrazine | ND | ND |
| 2,4-dinitrotoluene | ND | ND |
| N-nitrosodiphenylamine | ND | ND |
| hexachlorobenzene | ND | ND |
| 4-bromophenyl phenyl ether | ND | ND |
| phenanthrene | ND | ND |
| anthracene | 250 | <10 |
| dimethylphthalate | ND | ND |
| diethylphthalate | ND | ND |
| fluoranthene | 200 | <10 |
| pyrene | 150 | <10 |
| di-n-butylphthalate | ND | ND |
| benzidine | ND | ND |
| butyl benzylphthalate | ND | ND |
| di-n-octylphthalate | ND | ND |
| chrysene | 71 | ND |
| bis(2-ethylhexyl)phthalate | ND | <10 |
| benzo(a)anthracene | 71 | ND |
| benzo(b)fluoranthene | 38 | ND |
| benzo(k)fluoranthene | 1000 | ND |
| benzo(a)pyrene | 92 | ND |
| indeno(1,2,3-cd)pyrene | <10 | ND |

continued

ND = Not Detected.
<10 µg/L = Detected but at a level less than 10 µg/L.

TABLE 91 (continued).

| Compound | Ponds A & B Inlet Concentration µg/L | Pond D Outlet Concentration µg/L |
|---|---|---|
| dibenzo(a,h)anthracene | ND | ND |
| benzo(g,h,i)perylene | 15 | ND |
| N-nitrosodi-n-propylamine | ND | ND |
| 4-chloro-phenyl phenyl ether | ND | ND |
| 3,3'-dichlorobenzidine | ND | ND |
| 2,3,7,8-tetrachlorodibenzo-p-dioxin | ND | ND |
| bis(chloromethyl)ether | ND | ND |
| N-nitrosidimethylamine | ND | ND |

ND = Not Detected.
<10 µg/L = Detected but at a level less than 10 µg/L.

## TABLE 92. ACID EXTRACTABLE ORGANICS - PRIORITY POLLUTANT ANALYSIS

| Compound | Ponds A & B Inlet Concentration μg/L | Pond D Outlet Concentration μg/L |
|---|---|---|
| 2-chlorophenol | ND | 20 |
| phenol | 2200 | ND |
| 2,4-dichlorophenol | ND | 35 |
| 2-nitrophenol | ND | ND |
| p-chloro-m-cresol | ND | <10 |
| 2,4,6-trichlorophenol | ND | 35 |
| 2,4-dimethylphenol | 450 | <10 |
| 2,4-dinitrophenol | ND | ND |
| 4,6-dinitro-o-cresol | ND | ND |
| 4-nitrophenol | ND | ND |
| pentachlorophenol | ND | ND |

ND = Not Detected.
<10 μg/L = Detected but at a level less than 10 μg/L.

## TABLE 93. PESTICIDES AND PCBs - PRIORITY POLLUTANT ANALYSIS [a]

| Compound | Ponds A & B Inlet Concentration μg/L | Pond D Outlet Concentration μg/L |
|---|---|---|
| aldrin | ND | <1 |
| dieldrin | ND | ND |
| 4,4'-DDT | <10 | <10 |
| 4,4'-DDE (p,p'-DDE) | ND | ND |
| 4,4'-DDD (p,p'-TDE) | ND | <1 |
| α-endosulfan | ND | ND |
| β-endosulfan | ND | ND |
| endosulfan sulfate | <4* | ND |
| endrin | ND | ND |
| endrin aldehyde | <1 | <10 |
| heptachlor | <10 | <10 |
| heptachlor epoxide | ND | <1 |
| α-BHC | <1 | <10 |
| β-BHC | <10 | <10 |
| γ-BHC (lindane) | <1 | <10 |
| δ-BHC | <10* | <10 |
| toxaphene | <5* | <10 |
| chlordane | ND | <10 |
| PCB-(Aroclor)-1221 | <20* | <20 |
| PCB-(Aroclor)-1232 | ND | <2 |
| PCB-(Aroclor)-1242 | ND | <1 |
| PCB-(Aroclor)-1248 | ND | <1 |
| PCB-(Aroclor)-1254 | ND | <2 |
| PCB-(Aroclor)-1260 | ND | <2 |
| PCB-(aroclor)-1016 | ND | <1 |

ND = Not Detected.
<μg/L = Detected but at a level less than stated μg/L.
*Higher detection limit due to interference.

[a] These analyses done on Tracor Model 222 GC with $Ni^{63}$ electron capture and Tracor Model 700 Hall electrolytic conductivity detectors. Since PCB analyses by this technique is affected by some interferences, the PCB identifications cannot be considered proven.

TABLE 94. PRIORITY POLLUTANT ANALYSIS - METALS

| Compound | Ponds A & B Inlet Concentration mg/L | Pond D Outlet Concentration mg/L |
|---|---|---|
| copper | 0.56 | 0.006 |
| chromium | 0.19 | <0.01 |
| lead | 20.2 | 0.02 |
| mercury | <0.001 | <0.001 |
| nickel | 0.20 | <0.01 |
| selenium | 0.069 | <0.001 |
| silver | 0.02[illegible] | <0.002 |
| thallium | <0.01 | <0.01 |
| zinc | 10.1 | 0.025 |
| antimony | 0.52 | 0.029 |
| arsenic | 1.02 | 0.010 |
| beryllium | <0.001 | <0.001 |
| cadmium | 0.031 | <0.001 |

benzo(b)fluoranthene, benzo(a)pyrene, and chrysene) in addition to a variety of metals and two types of phenols.

The treated water discharged was significantly reduced in concentration of all these materials. None of the carcinogenic PNAs were detected. Two features are, however, noteworthy. Several chlorinated phenols appear in the effluent sample but not in the influent. The outlet sample also contained several pesticides and PCBs not detected, or at higher concentrations than detected, in the influent sample. The source of these compounds in the inlet sample was not investigated but they may have been in the plant intake water from Lake Erie. If the PCB identifications are correct, we can only conclude that the appearance of additional PCB in the treated water is a direct result of chlorinating the wastewater. The PCB concentrations in the discharged water may be sufficiently high to be of regulatory concern.

## 9.6 LEACHING TEST, SOLIDS IN WWT POND INLET SLURRY

The plant slurries all dusts collected by the emission control equipment and discharges this to the wastewater treatment ponds. The solids, which settle out before the chlorination step, are dredged out and landfilled. Rather than trying to obtain a sample of the dredgings or of the material in the landfill, a composite sample of the pond influent was obtained and the solids filtered out. We believe this is a good representation of the material which will eventually be landfilled.

The solids filtered from the influent water were analyzed by AAS for nine metals on EPA's Priority Pollutant list. All of the elements, except thallium and possibly mercury, are present (see Table 95) in concentrations which may be of some concern.

The solids were then subjected to leaching following procedures given in the Federal Register 40 CFR Part 261, Appendix II, May 19, 1980. The leachate analysis is given in column 3 of Table 95. None of the elements equal or exceed the permissible concentration given in 40 CFR Part 261.24. Thus, on this basis the solid is nonhazardous. This is in agreement with the groundwater analyses given below.

Given in the last columns of the table are the actual amount extracted and the percentage of the element extracted. In general, less than 2 percent

TABLE 95. LEACHING TEST RESULTS, ASHTABULA PLANT WWT POND INLET SOLIDS

| Element | Concentration in Original Sample, μg/g Solid | Concentration in Leachate, mg/L | Amount Leached, μg/g Solids | % of Element |
|---|---|---|---|---|
| Antimony | 16.6 | 0.0376 | 0.752 | 4.5 |
| Arsenic[a] | 289 | 0.289 | 5.77 | 2.0 |
| Beryllium | 0.564 | $<3 \times 10^{-5}$ | $<6 \times 10^{-4}$ | 0.1 |
| Cadmium | 7.65 | $<1 \times 10^{-4}$ | $<2 \times 10^{-3}$ | $2.6 \times 10^{-2}$ |
| Chromium | 148 | 0.630 | 12.6 | 8.5 |
| Lead | 4720 | $<1 \times 10^{-3}$ | $<2 \times 10^{-2}$ | $4 \times 10^{-4}$ |
| Mercury | <0.62 | $<1.2 \times 10^{-2}$ | <0.25 | ? |
| Selenium | 23.0 | $8.13 \times 10^{-2}$ | 1.63 | 7.1 |
| Thallium | 2.20 | $5.1 \times 10^{-4}$ | $1.01 \times 10^{-2}$ | 0.46 |

[a] Possible analytical interference.

of the element was extracted. Exception to this are antimony (4.5 percent), chromium (8.5 percent), and selenium (7.1 percent).

## 9.7 GROUNDWATER

Samples were obtained at the Ashtabula plant (see Figure 12) of the groundwater immediately up-gradient and immediately down-gradient of the landfill--wastewater treatment pond area.

RTI analyzed these samples for organics and BaP. Both components were below the detection limits. Since only 1 liter of each sample could be obtained, the detection limits are somewhat higher than for other samples obtained. The detection limits are: for organics, 0.1 mg/L; for BaP, 0.5 μg/L.

Included in Table 96 are the concentrations of metals in the groundwaters. The results were supplied to RTI by the company. The company routinely reports these analyses to the Ohio Environmental Protection Agency.

As can be seen from the table, only four elements (Al, Mg, Mn, and Ni) had a higher concentration down-gradient of the waste treatment area than existed in the up-gradient water. Furthermore, the data show that several metals actually decreased in concentration.

Based on these limited data, it does not appear that there is any significant leaching of materials in the landfill or percolation of water from the wastewater treatment ponds into the underlying aquifer.

## TABLE 96. ANALYSIS OF GROUNDWATER AT ASHTABULA[a]

| Component | Up-Gradient mg/L | Down-gradient mg/L |
|---|---|---|
| Al | 0.31 | 1.51 |
| Cd | 0.005 | <0.002 |
| Cr | <0.001 | <0.001 |
| Cu | 0.025 | 0.020 |
| Fe | 22.0 | 0.80 |
| Mg | 65.5 | 120.9 |
| Mn | 1.21 | 1.88 |
| Ni | 0.010 | 0.025 |
| Pb | <0.01 | <0.01 |
| Zn | 0.074 | 0.060 |
| Organics | <0.1 | <0.1 |
| BaP | <0.0005 | <0.0005 |

[a] Metals analysis supplied by company and reported to Ohio Environmental Protection Agency. Samples taken immediately up- and down-gradient of the landfill--wastewater treatment area.

# 10. TESTING OF COVERED FURNACE PRODUCING H.C. FeMn

These tests were done on furnace No.17 and associated control equipment at Union Carbide Corporation plant in Marietta, Ohio (now owned by Elkem Metals Company) on March 11 and 12, 1981.

## 10.1 SITE DESCRIPTION

### 10.1.1 General Plant

The plant is located adjacent to the Ohio River (see Figure 18). SiMn, FeMn and FeCr are produced in submerged arc furnaces. Refining of some ferroalloys is accomplished in a high temperature vacuum operation (referred to as the Simplex plant). High purity -- $99.8^+$ percent -- chromium as well as Mn, and $MnO_2$ are produced in three separate electrolytic units.

There are nine submerged arc furnaces (not all currently operating) at the plant. Two of the furnaces are the open type, rated at 15 and 30 MW and normally produce FeMn, and SiMn, respectively. The remaining seven furnaces are covered (semi-enclosed) types. Five of these, with power ratings between 8 and 13 MW, produce H.C. FeMn. The remaining two covered furnaces, both rated at 12 MW produce FeCr.

Wet scrubbers are used to control fumes generated by all furnaces. For open furnaces, these scrubbers control all furnace fume. For covered furnaces, the scrubbers control only the fume withdrawn from beneath the covers. Secondary fumes escaping the furnace covers are exhausted directly to atmosphere. Control of tapping fumes is practiced on two of the covered furnaces and one of the open furnaces.

All process water from the electrolytic operation is collected, adjusted to pH 9.2 with lime and oxidized by oxygen in a $\text{UNOX}^R$ treatment system. This treated water, which contains an oxygen residual, is mixed with scrubber discharge water from the furnaces and discharged into the first of several

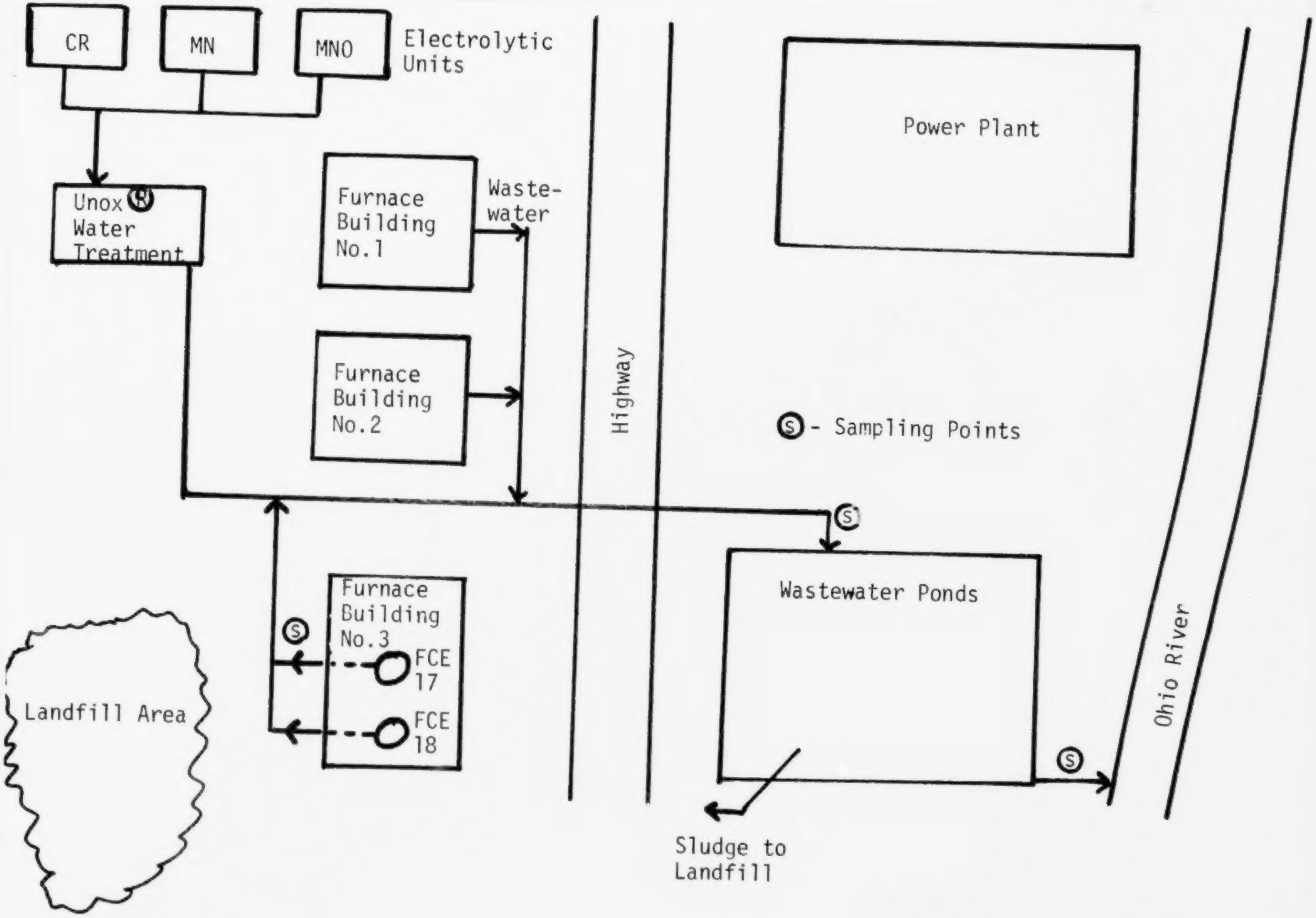
CR
MN
MNO
Electrolytic Units
Unox ® Water Treatment
Furnace Building No.1
Furnace Building No.2
Furnace Building No.3
Waste-water
FCE 17
FCE 18
S
Landfill Area
Highway
Power Plant
S - Sampling Points
S
Wastewater Ponds
Sludge to Landfill
S
Ohio River

Figure 18. Schematic - plant layout.

ponds occupying a total of about 100 acres near the river. Once-through cooling water and sanitary water do not enter this system and are discharged separately.

Solids contained in the wastewater settle out in the ponds and are occasionally dredged out and landfilled in a diked impoundment located behind the plant well away from the river. The clarified water discharged from the ponds flows into the Ohio River.

### 10.1.2 Description of Furnace No.17 and Associated Pollution Capture Equipment

Testing at this plant was for fumes generated and emitted from furnace No.17 and for wastewater quality entering and being discharged from the final treatment ponds.

Furnace No.17 (see Figure 19) is a covered type with a design rating of 8 MW. Fumes withdrawn from beneath the cover are controlled with a Buffalo Forge disintegrator type scrubber. Secondary fumes escaping the cover are contained by a hood mounted above the furnace and exhaust directly to the atmosphere through four gravity stacks. No exhaust fans are used; draft is provided by the natural buoyancy of the hot gas rising from the furnace cover. Tapping fumes are not controlled. Power is supplied to the furnace through three 0.89 meter (35 inch) diameter prebaked carbon electrodes.

Raw materials are premixed and delivered via a "trip" car to storage bins above the furnace. Raw material is discharged from the storage bins onto the furnace cover in the area around the electrodes as needed to maintain a gas seal. The material charged descends into the furnace through annular spaces between the cover and the electrodes, as required by the furnace. Raw material consumption is monitored by counting the number of batches delivered by the "trip" car.

There is one taphole in the furnace. The furnace does not rotate. A small amount, perhaps 1-5 percent, of the tap fume enters the hood above the furnace. During tapping, slag and alloy flow into skimmers below the taphole, where they are separated. After the metal is tapped out, carbon paste is forced into the taphole to plug it. The alloy produced is mixed with FeMn alloy from furnace No.18, poured into chills, and cooled.

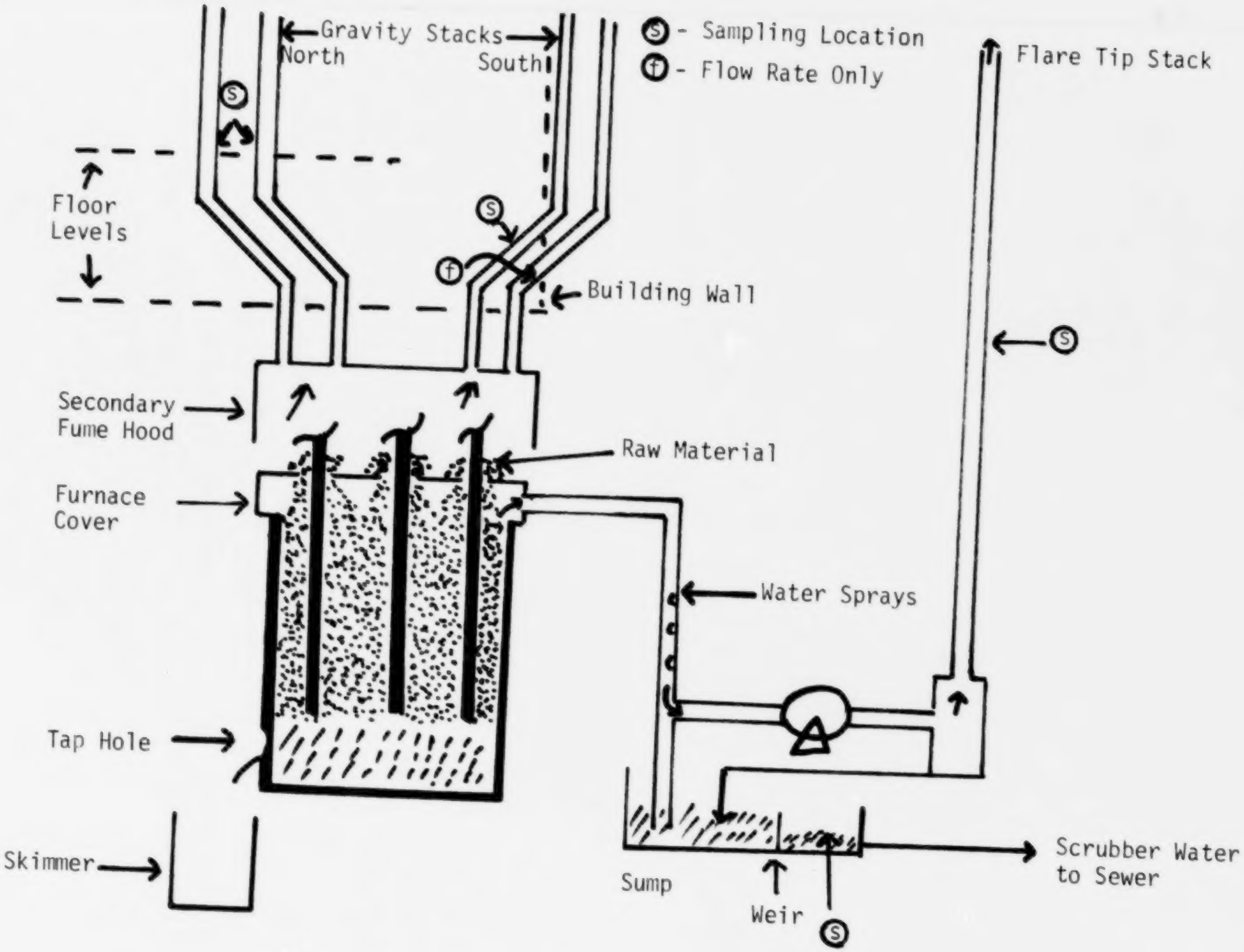
Gravity Stacks
North
South
S - Sampling Location
f - Flow Rate Only
Flare Tip Stack
S
Floor Levels
S
f
Building Wall
S
Secondary Fume Hood
Raw Material
Furnace Cover
Water Sprays
Tap Hole
Skimmer
Sump
Weir
S
Scrubber Water to Sewer

Figure 19. Schematic of furnace No.17 and emission control system.

The furnace cover does not fit tightly on furnace No.17. As a result some ambient air is drawn into the space beneath the cover. This ambient air mixes with furnace produced gas and some combustion of the gas occurs under the cover. The carbon monoxide content of the gas passing through the scrubber is sufficiently low that the gas seldom can be flared although provisions for flaring the gas are incorporated in the discharge stack.

Water from the Ohio River is used, on a once-through basis, in the scrubber. Scrubber discharge water is combined with water from the electrolytic operations after treatment in the UNOX$^R$ system and discharged to the wastewater ponds.

## 10.2 PROCESS CONTROL

Furnace No.17 is used to produce FeMn product only. The furnace is operated such that the slag contains a high manganese content which is recovered in other plant operations. FeMn alloy is produced by mixing manganese ore, iron scrap, carbon in the form of coke and silicon in the form of gravel. This mixture is heated to a sufficiently high temperature that the primary reactions

$$MnO + C \rightarrow Mn + CO$$

$$Fe \text{ solid} \rightarrow Fe \text{ (liquid)}$$

$$MnO \rightarrow \text{dissolves in slag}$$

occur. Heat is supplied by power input through the electrodes.

The furnace operation is controlled by adjusting the type and ratio of raw materials and varying the power input. Power input can be adjusted by varying the applied voltage and/or moving the electrodes vertically. The furnace is not stoked.

## 10.3 TEST DESCRIPTION

Figure 19 is a schematic of furnace 17 and the related pollution control equipment. Sample point locations are identified in the figure. Figures 20-25 gives more detail on the sample point locations.

A gas sample could not be obtained of the fumes withdrawn from beneath the cover because of the presence of water sprays in the duct. To determine

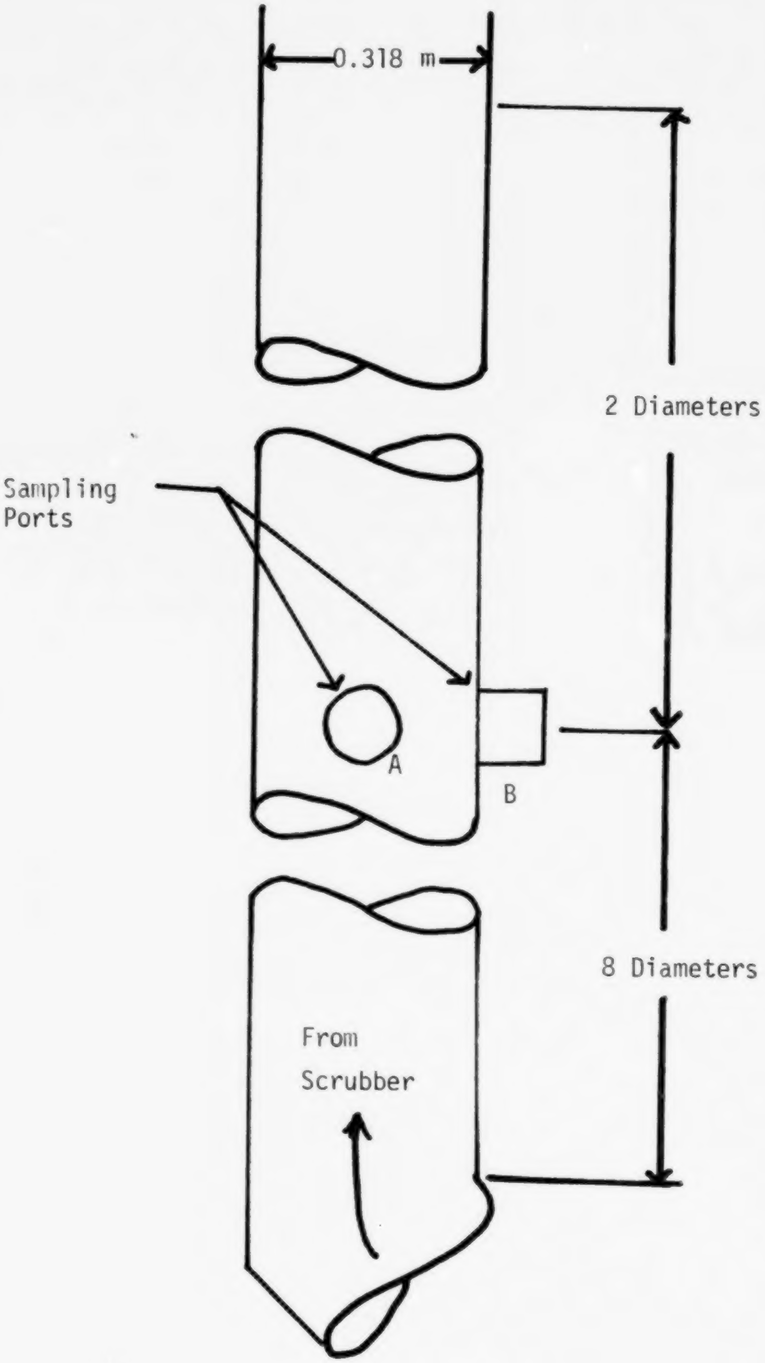
0.318 m
2 Diameters
Sampling Ports
A
B
8 Diameters
From Scrubber

Figure 20. Scrubber stack dimensions.

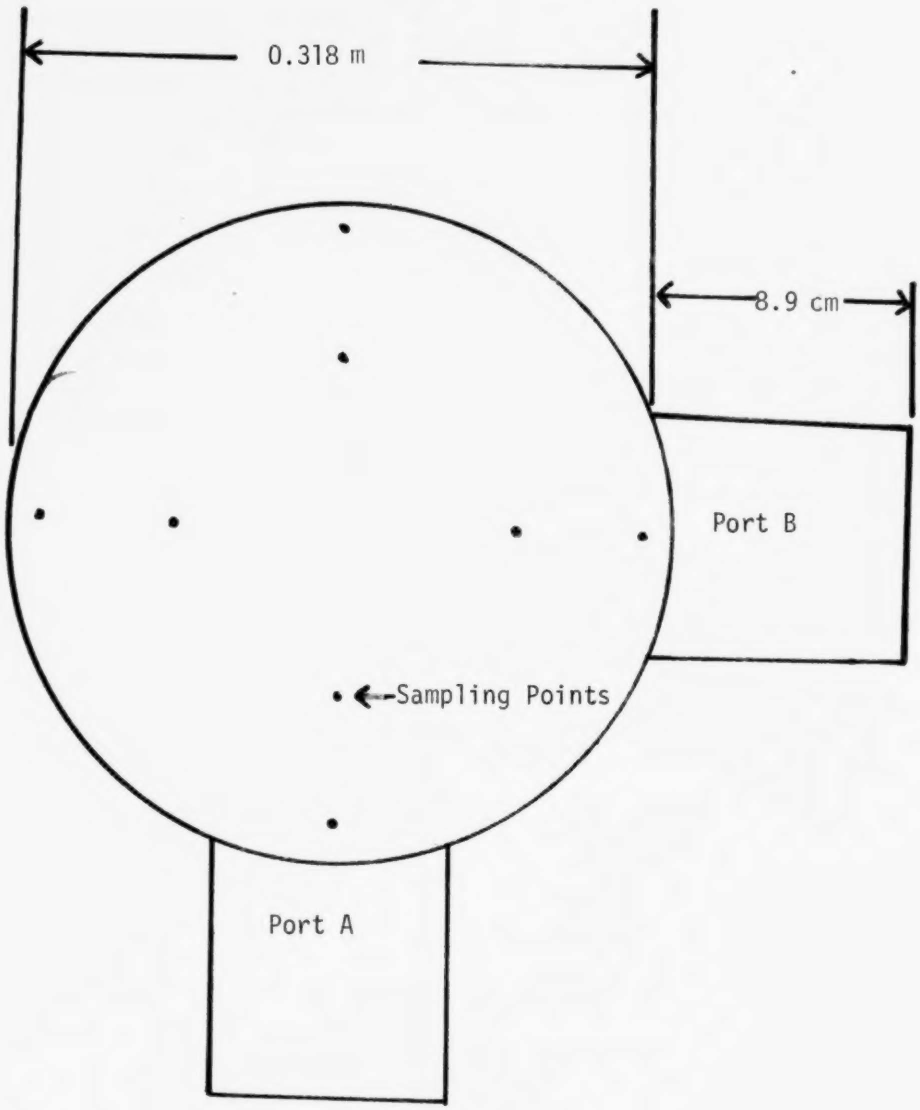
0.318 m
8.9 cm
Port B
Sampling Points
Port A

Figure 21. Scrubber stack cross-section.

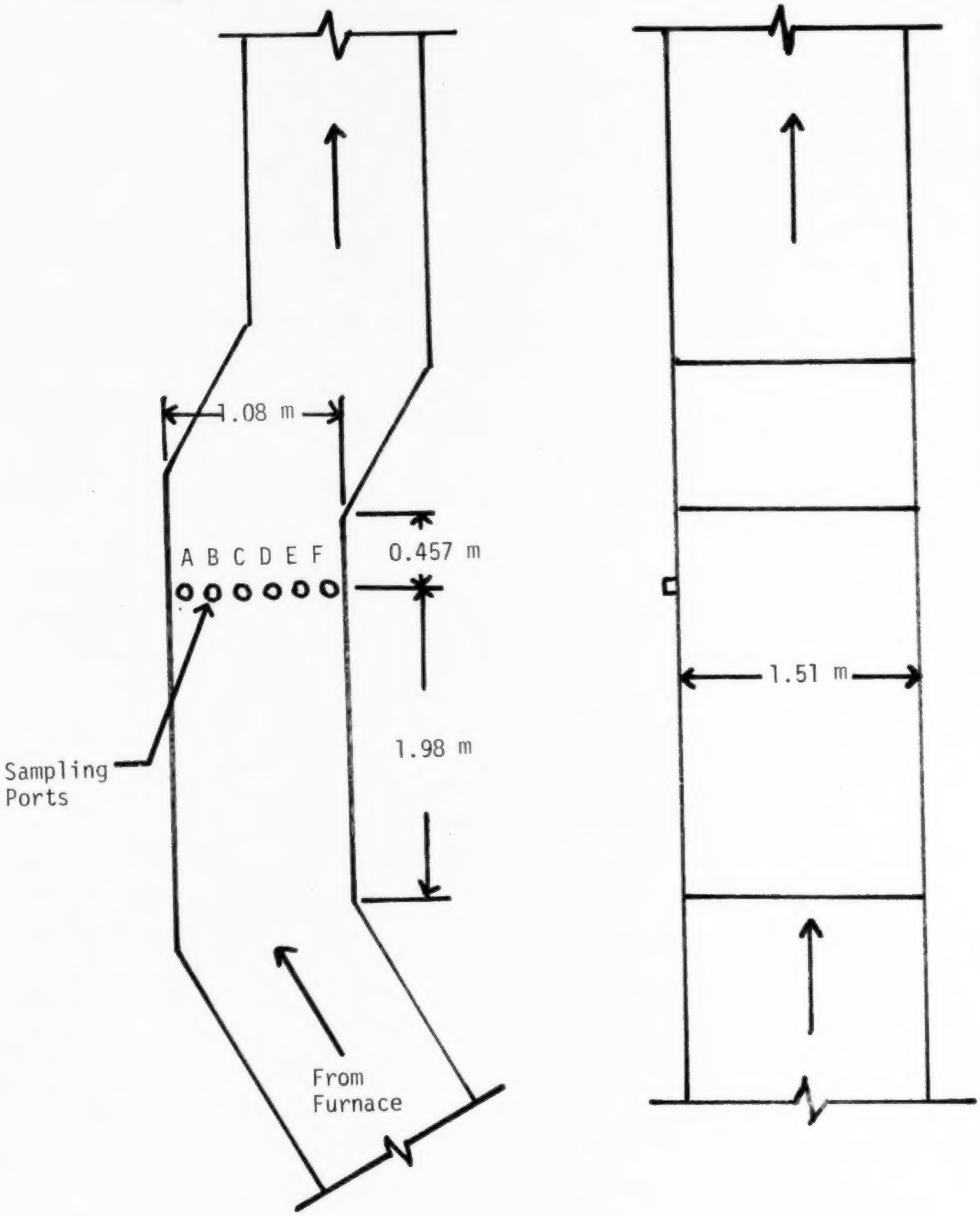
1.08 m
A B C D E F
0.457 m
Sampling Ports
1.98 m
From Furnace
1.51 m

Figure 22. North stack dimensions.

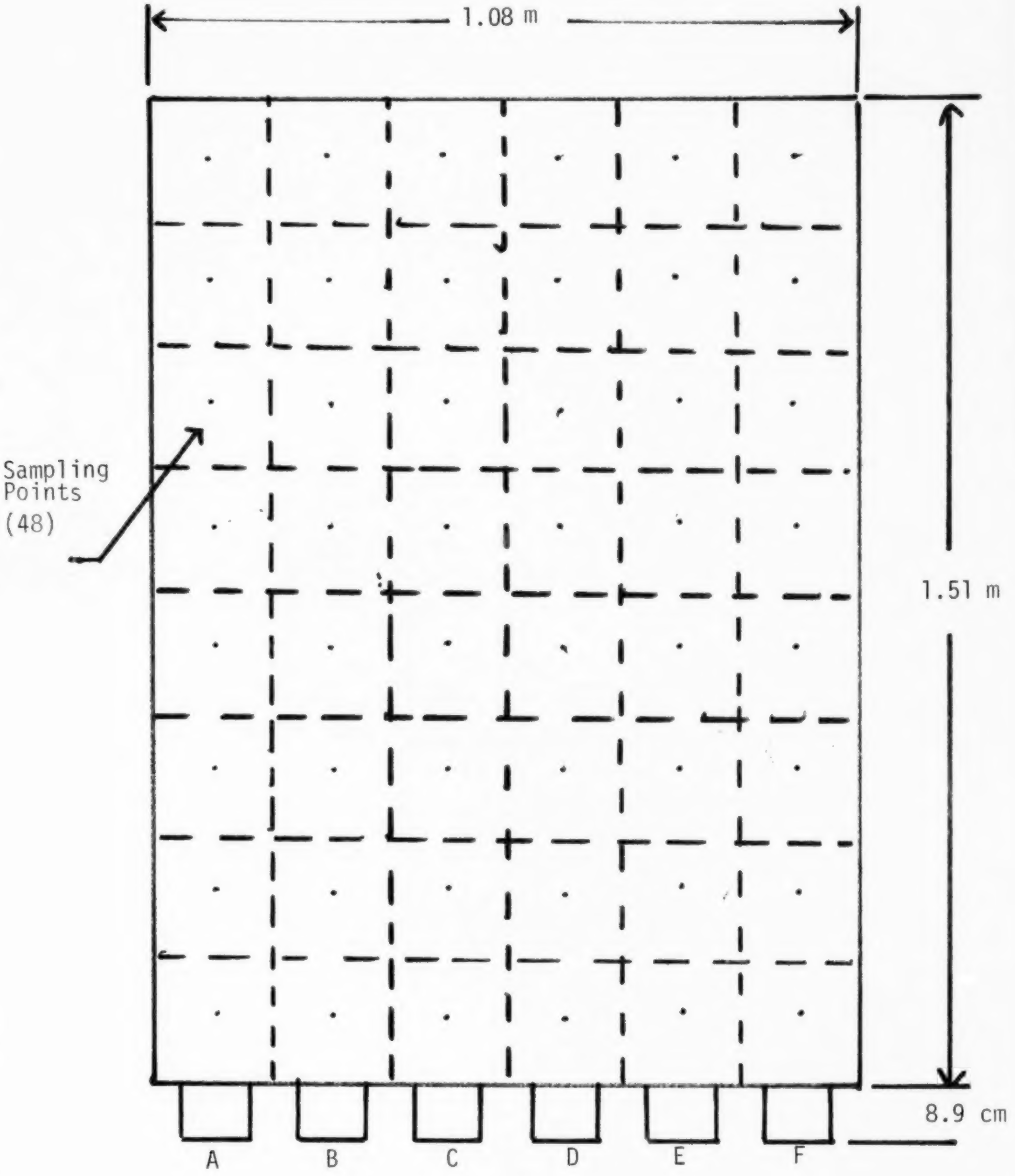
1.08 m
1.51 m
8.9 cm
Sampling Points (48)
A
B
C
D
E
F

Figure 23. North stack cross-section.

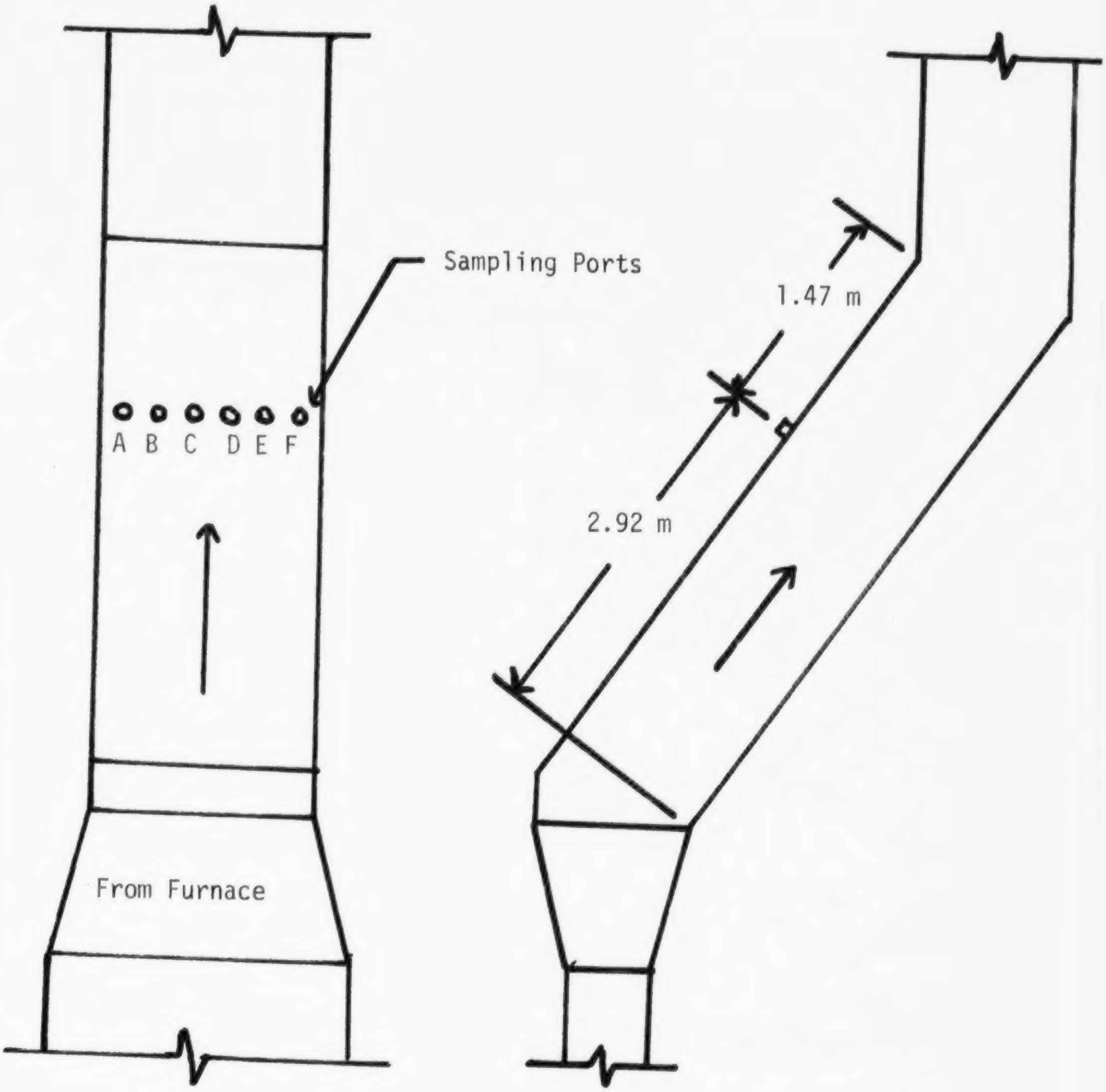
Sampling Ports
A B C D E F
From Furnace
1.47 m
2.92 m

Figure 24. South stack dimensions.

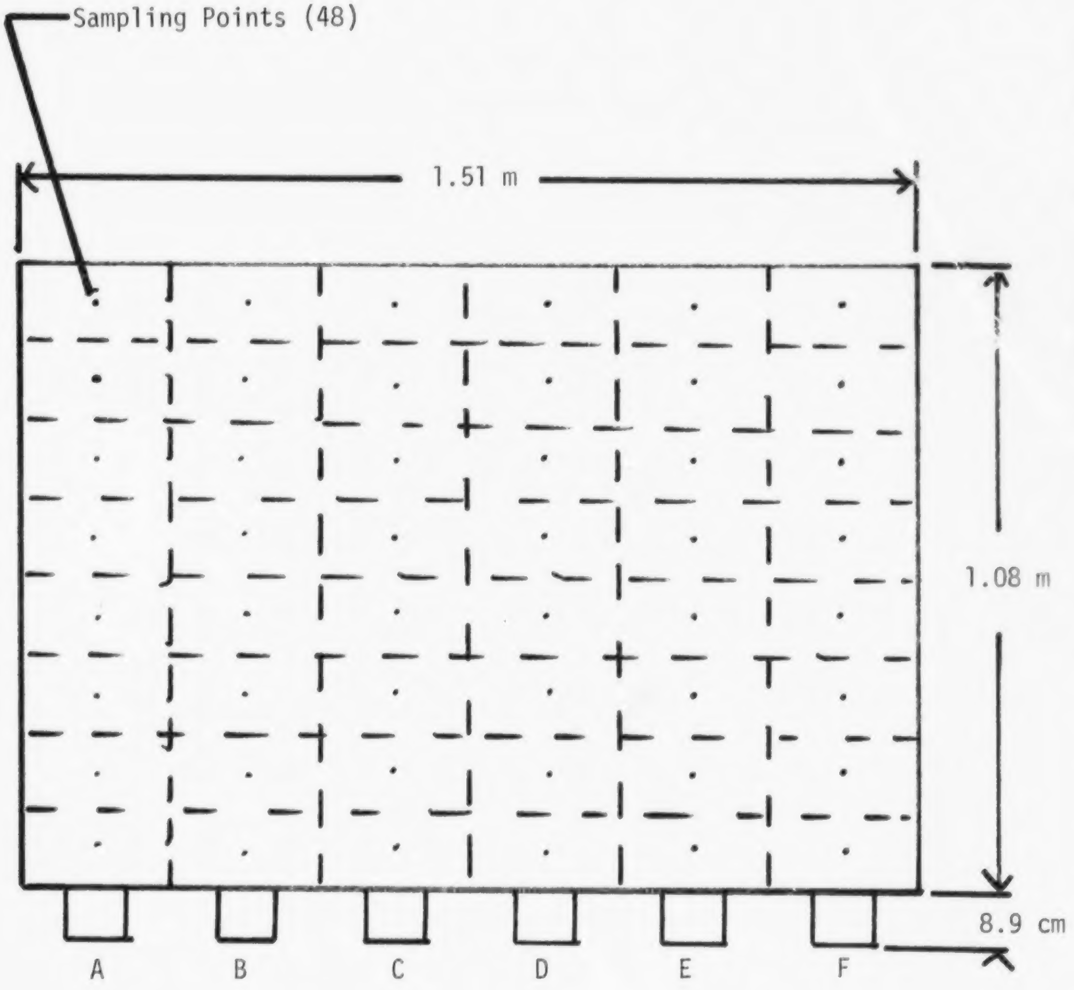
Sampling Points (48)
1.51 m
1.08 m
8.9 cm
A
B
C
D
E
F

Figure 25. South stack cross-section.

the amount of materials going to the scrubber, samples were taken of the scrubber feed water, the scrubber discharge water, and the scrubber outlet gas.

As shown, the scrubber outlet sample ports were located at a 90° angle in the vertical 0.3175 meters (12.5 inches) inside diameter duct. There were no flow disturbances within 3 meters (10 feet) of the sample point. Four points were sampled in each traverse axis, 8 points total for each test.

Secondary fumes collected by the hood above the furnace cover exit to the atmosphere through four separate stacks designated northeast, northwest, southeast and southwest. The northeast and southwest stacks are equipped with opacity monitoring equipment. The two stacks on the north side are vertical and rectangular with dimensions of 1.51 by 1.08 meters (59.5 x 42.5 inches). The nearest flow disturbances from the sample point for these stacks were: upstream from sample point, 1.57 equivalent stack diameters; downstream of sample point, 0.36 equivalent stack diameters. Six ports were installed in one of the 1.08 meter walls of each stack. An eight point traverse was made through each of the six ports for each test (48 points total each test). A velocity traverse was made in the south ducts to determine their flow rate during testing on the north stacks. Three tests were performed on 3/11/81, simultaneously with scrubber testing, in the northeast, northwest, and northeast stacks, respectively.

The duct dimensions of the two south stacks are identical to those of the north stacks. At the only feasible sample location, the ducts are inclined at about a 30 degree (from vertical) angle. Six sample ports were installed in the 1.51 meter walls of the ducts. An eight point traverse was made in each port for each test (48 points total for each test). Velocity traverses were made in the north stacks during tests on the southeast stack. Two tests were performed, simultaneously with scrubber testing, in the southeast duct on 3/12/81. Time restrictions, due to a furnace outage to repair a water leak, prevented sampling the southwest duct.

Sampling at the scrubber outlet and the gravity stacks was done by EPA Methods 1-5, as applicable (see Appendix for details of test methods) with the same exceptions given in Section 7 (page 99).

Scrubber discharge water samples were collected simultaneously with scrubber outlet gas sampling. The samples were taken from the scrubber local sump overflow weir using an automatic, composite water sampler. Scrubber water discharge flow rate was determined by calculation from dimensions of the overflow weir. Effective width of the weir was 0.45 meters (17.75 inches), water height above weir was 0.1125 meters (4.5 inches).

Twenty-four hour composite samples were also taken of the influent to and the discharge from the wastewater treatment ponds.

Simultaneously with the sampling activities, process information was collected which included raw materials fed, power consumed, furnace operating conditions, alloy and slag analyses, and sufficient information to calculate the amount of slag and alloy produced. Since the products of furnace Nos.17 and 18 are mixed before weighing, the amount produced must be calculated. The method used is the same as used by the plant for this purpose (see discussion of Table 101 in this section).

Given in Tables 97 and 98 are the pertinent sampling data for the scrubber outlet and gravity stacks. The gravity stack actually sampled for each test is indicated and the measured flow rate in that stack given. Also given is the estimated total flow rate for all four stacks. This flow rate was estimated as follows, using Run No.1 as an example. The flow rate through each gravity stack is somewhat independent of the flow through the other gravity stacks and depends primarily on the gas temperature at the furnace cover directly below the stack offtake. Although previous tests by the company indicated that the stack flow rates were independent, during these particular tests, the flow rates through both of the north stacks appeared to be quite similar and the flow rates through both of the south stacks, although possibly quite different than the north stacks, also appeared to be quite similar. During the testing on the north stacks, velocity traverses, to determine gas flow rate, were made on both south stacks. The flow rate through the north stack not being tested was assumed to be the same as through the north stack being tested. Test data for Runs 1, 2, and 3 tend to substantiate this assumption. The total flow rate was thus calculated by multiplying the flow rate through the stack being tested

TABLE 97. SCRUBBER OUTLET GAS SAMPLING DATA

| Run No.<br>Date | 1<br>3/11/81 | 2<br>3/11/81 | 3<br>3/11/81 | 4<br>3/12/81 | 5<br>3/12/81 |
|---|---|---|---|---|---|
| Start Time | 0925 | 1200 | 1445 | 0845 | 1407 |
| Stop Time | 1105 | 1351 | 1623 | 1330 | 1606 |
| Net Sampling Time, min | 96 | 96 | 96 | 96 | 96 |
| Stack Temperature, °C | 17 | 16 | 15 | 17 | 15 |
| Stack Flow Rate dsm$^3$/min | 58.81 | 56.29 | 57.17 | 56.80 | 58.22 |
| Stack Flow Rate A m$^3$/min | 60.23 | 57.03 | 58.08 | 58.30 | 59.38 |
| Volume Collected dsm$^3$ | 1.0226 | 0.9728 | 0.9356 | 1.0140 | 1.0029 |
| Percent Isokinetic | 101.6 | 100.9 | 95.6 | 104.3 | 100.6 |

TABLE 98. GRAVITY STACK SAMPLING DATA

| Run No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Date | 3/11/81 | 3/11/81 | 3/11/81 | 3/12/81 | 3/12/81 |
| Start Time | 0917 | 1153 | 1422 | 0845 | 1405 |
| Stop Time | 1112 | 1407 | 1628 | 1342 | 1613 |
| Net Sampling Time, min | 96 | 96 | 96 | 96 | 96 |
| Stack Temperature, °C | 11 | 9 | 12 | 22 | 26 |
| Stack Sampled | NW | NE | NW | SE | SE |
| Stack Flow Rate dsm$^3$/min | 139.91 | 123.21 | 117.91 | 194.76 | 161.12 |
| Stack Flow Rate A m$^3$/min | 139.57 | 122.33 | 118.22 | 203.34 | 170.50 |
| Total Stack Flow Rate (all 4 stacks), dsm$^3$/min | 1,080 | 1,050 | 1,030 | 920 | 870 |
| Volume Collected dsm$^3$ | 1.0572 | 0.9399 | 0.8968 | 1.6393 | 1.3670 |
| Percent Isokinetic | 95.4 | 96.3 | 96.1 | 106.3 | 107.2 |

by two and adding the flow rates of the south stacks determined by velocity traverse. The identical procedure was used for testing on the south stacks.

Given in Table 99 are the raw material consumption data for the test period. The low raw material consumption figures for the 8 a.m.-4 p.m. shift on 3/12/81 are due to a lengthy furnace outage to repair a water leak. The ratio of raw materials fed was identical for all shifts except the 12 midnight to 8 a.m. shift of 3/11/81, during which the ratio of coke No.2 added was lower. The mix fed contained very little fines. The weight of electrode consumed is not included in the data given since determining this value over a short time period is difficult and highly inaccurate. For those wishing to include electrode consumption, a rate of about 8.2 Kg (18 lb) per MW-hr is reported by the plant as a long term average.

Given in Table 100 are the instantaneous power load of the furnace and the cumulative MW-hr meter readings. Also included are shift summary data for operating hours, average loads while operating, and total MW-hr consumed.

Given in Table 101 are the tap times occurring during testing (not particularly significant since tap fumes are not controlled), the weight of alloy and slag produced, and the alloy and slag analysis. The weights of alloy and slag produced are calculated values since the plant weighs the product of furnaces 17 and 18 together. Tap analyses are, however, determined separately. These weights were calculated, following plant practice, as follows. The plant reports that 1.19 kw-hr are used to produce 1 lb of alloy (2.6235 kw-hr/Kg alloy). Thus, for the 8 a.m. to 4 p.m. shift of 3/11/81, when power consumption was 56 MW-hr, the weight of alloy produced is [56 MW-hr ÷ 2.6235 MW-hr/Mg alloy = 21,346 Kg alloy]. The plant also reports that 0.814 Kg of slag are produced per Kg of alloy. Thus, slag produced on the above shift is 0.814 x 21,346 Kg alloy = 17,375 Kg slag. This procedure was followed for all calculations presented.

## 10.4 TEST RESULTS

### 10.4.1 Gas Analysis

Samples of scrubber outlet gas were taken during Runs No.2 (1200-1351 on 3/11/81) and 4 (0845-1330 on 3/12/81) and an Orsat analysis performed. The results are given in Table 102.

TABLE 99. RAW MATERIAL CONSUMPTION, FURNACE 17 (in Kg)

| Date<br>Shift | 3/11/81<br>12-8 | 3/11/81<br>8-4 | 3/11/81<br>4-12 | 3/12/81<br>12-8 | 3/12/81<br>8-4 |
|---|---|---|---|---|---|
| Mn Ore | 66,678 | 60,010 | 66,678 | 66,678 | 23,337 |
| Millscale | 2,540 | 2,286 | 2,540 | 2,540 | 889 |
| Standard H.C. FeMn Fines | 907 | 816 | 907 | 907 | 318 |
| Gravel | 3,084 | 2,776 | 3,084 | 3,084 | 1,080 |
| Coke No.1 | 1,814 | 1,633 | 1,814 | 1,814 | 635 |
| Coke No.2 | 11,213 | 10,532 | 11,703 | 11,703 | 4,096 |
| Total: | 86,236 | 78,053 | 86,726 | 86,726 | 30,355 |

## TABLE 100. POWER CONSUMPTION RECORD, FURNACE NO.17 CONTROL ROOM READING

| Date | Time | Instantaneous Load, MW | Cumulative MW-hrs |
|---|---|---|---|
| 3/11/81 | 910 | 7.2 | 7,866.5 |
| | 931 | 7.2 | 7,869.0 |
| | 1005 | 7.0 | 7,873.2 |
| | 1023 | 7.0 | 7,875.7 |
| | 1040 | 7.0 | 7,877.5 |
| | 1106 | 7.0 | 7,880.8 |
| | 1159 | 6.8 | 7,886.8 |
| | 1220 | 6.9 | 7,889.2 |
| | 1240 | Shutdown | 7,891.2 |
| | 1250 | Restart (6.5) | |
| | 1343 | 7.0 | 7,897.5 |
| | 1406 | 6.9 | 7,900.2 |
| | 1445 | 7.0 | 7,904.8 |
| | 1535 | 7.0 | 7,910.9 |
| | 1555 | 7.0 | 7,913.2 |
| | 1622 | 7.0 | 7,916.4 |
| 3/12/81 | 800 | 6.6 | 8,029.8 |
| | 805 | Shutdown | |
| | 827 | Restart | |
| | 834 | 7.5 | 8,031.9 |
| | 843 | 6.6 | 8,033.0 |
| | 932 | Shutdown | 8,038.3 |
| | 1209 | Restart | |
| | 1242 | 6.7 | 8,041.8 |
| | 1328 | 6.5 | 8,046.7 |
| | 1406 | 6.9 | 8,050.8 |
| | 1414 | Shutdown | |
| | 1425 | Restart | |
| | 1430 | 6.9 | 8,051.8 |
| | 1448 | 5.6 | 8,054.0 |
| | 1514 | Shutdown | |
| | 1522 | Restart | |
| | 1525 | 6.3 | 8,056.8 |
| | 1545 | 6.0 | 8,059.0 |
| | 1600 | 6.1 | 8,060.3 |

continued

TABLE 100 (continued).

SUMMARY DATA

| Date | Shift | Actual Operating Hours | Average Load While Operating MW | Total Power Used MW-hrs |
|---|---|---|---|---|
| 3/11/81 | 12-8 | 7.43 | 8.345 | 62.00 |
| | 8-4 | 7.77 | 7.207 | 56.00 |
| | 4-12 | 8.0 | 7.413 | 59.30 |
| 3/12/81 | 12-8 | 7.58 | 7.678 | 58.20 |
| | 8-4 | 4.67 | 6.531 | 30.50 |

## TABLE 101. TAPPING DATA

| Date | Tap Open | Tap Closed | Alloy Produced, Kg 8-4 Shift | Alloy Produced, Kg Day | Slag Produced, Kg 8-4 Shift | Slag Produced, Kg Day |
|---|---|---|---|---|---|---|
| 3/11/81 | 950 | 1001 | 21,346 | 67,851 | 17,375 | 54,844 |
| | 1140 | 1155 | | | | |
| | 1350 | 1407 | | | | |
| 3/12/81 | 843 | 930 | 11,626 | 53,326 | 9,463 | 43,407 |
| | 1500 | 1514 | | | | |

### TAP ANALYSIS, IN PERCENT

| Date | Component | Day Average | High | Low |
|---|---|---|---|---|
| 3/11/81 | Mn | 80.25 | 81.09 | 80.25 |
| | Cr | 0.05 | 0.07 | 0.04 |
| | Si | 0.88 | 1.55 | 0.45 |
| | Fe | 11.32 | 13.13 | 10.39 |
| | C | 6.8 (estimated) | | |
| 3/12/81 | Mn | 81.75 | 82.05 | 81.5 |
| | Cr | 0.07 | 0.09 | 0.05 |
| | Si | 0.57 | 0.89 | 0.30 |
| | Fe | 10.07 | 10.29 | 9.95 |
| | C | 6.8 (estimated) | | |

### SLAG ANALYSIS, DAY AVERAGE, IN PERCENT

| Date | MnO | $SiO_2$ | FeO | $Al_2O_3$ | CaO | $K_2O$ |
|---|---|---|---|---|---|---|
| 3/11/81 | 52.93 | 19.60 | 0.46 | 19.22 | 1.50 | 2.68 |
| 3/12/81 | 56.17 | 18.04 | 1.01 | 18.23 | 1.21 | 2.77 |

These data indicate that substantial, but not complete, combustion of furnace gas is occurring under the furnace cover. This is consistent with process observer reports that the cover is not tightly sealed and that fire under the cover was visible through gaps in the cover-furnace seals.

TABLE 102. ORSAT ANALYSES, SCRUBBER OUTLET

| Component | Percent by Volume Run No.2 | Percent by Volume Run No.4 |
|---|---|---|
| $O_2$ | 9.0 | 10.0 |
| $N_2$ | 42.0 | 56.0 |
| $CO_2$ | 33.0 | 25.4 |
| CO | 16 | 8.6 |

A gas sample was also collected during Run No.2 at the gravity stacks and subjected to an Orsat analysis. The results are given in Table 103.

TABLE 103. ORSAT ANALYSIS, GRAVITY STACK

| Component | Percent by Volume |
|---|---|
| $O_2$ | 20 |
| $N_2$ | 80 |
| $CO_2$ | 0 |
| CO | 0 |

The results indicate that little, if any, furnace gas gets into the stack without being combusted. It also suggests that most of the gas going up the stack is ambient air.

### 10.4.2 Particulates

Given in Table 104 are the results obtained for particulate matter in the scrubber discharge gas. Particulate concentration in the gas aver aged about 18 mg/dsm$^3$, with an approximate range of 13 to 22 mg/dsm$^3$. Total particulate emitted through the scrubber stack averaged 0.062 Kg/operating hour. In terms of operating parameters, particulate emissions from the scrubber averaged $9.4 \times 10^{-3}$ Kg per MW-hr, $8.1 \times 10^{-3}$ Kg per Mg raw material fed, and $2.5 \times 10^{-2}$ Kg per Mg alloy produced.

Given in Table 105 are the results, corrected for particulate in the inlet water, obtained for particulate matter in the scrubber discharge water. Particulate concentration in the discharged water averaged about 92 mg/liter. Total particulates captured by the scrubber averaged 10.6 Kg/operating hour. In terms of operating parameters, the average amount of particulate captured by the scrubber was about 1.6 Kg/MW-hr, 1.3 Kg/Mg raw material fed, and 4.2 Kg/Mg alloy produced.

Given in Table 106 are the particulate results obtained for particulate matter emitted by the gravity stacks. These numbers were calculated from the concentrations measured in the stack tested and the total estimated flow rate for all four stacks as discussed previously. The assumption made is that the particulate concentration was the same in all stacks regardless of the individual flow rates. This assumption is undoubtedly not correct. It is likely that the particulate concentration increases with increasing gas flow rate since the higher flow rates are produced by high temperatures above the furnace cover caused by hot gas breaking through the mix seals around the electrodes. In all cases, the flow rate through the stack tested was less than through the remaining stacks as determined by velocity traverses. It is quite likely, therefore, that the results obtained for the gravity stacks are somewhat less than actual. It would have been preferable to avoid having to make the above assumptions. This could have been avoided only by having five test crews (one each for the scrubber stack and the four gravity stacks) on-site. The EPA Project Officer and RTI both felt this would be too great an expense considering the funding limitations of the project.

## TABLE 104. PARTICULATES, SCRUBBER OUTLET GAS

| Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Emitted per hour Kg | Average Load During Test MW-hr/hr | Emitted per MW-hr Kg | Emitted per Mg feed Kg | Emitted per Mg Alloy Kg |
|---|---|---|---|---|---|---|---|
| 1 | 16.7 | 16.33 | 0.058 | 7.40 | 0.0078 | 0.0056 | 0.021 |
| 2 | 12.7 | 13.06 | 0.044 | 6.87 | 0.0064 | 0.0046 | 0.017 |
| 3 | 17.3 | 18.49 | 0.063 | 7.18 | 0.0088 | 0.0063 | 0.023 |
| 4 | 20.8 | 20.51 | 0.070 | 6.42 | 0.011 | 0.011 | 0.029 |
| 5 | 21.9 | 21.84 | 0.076 | 6.00 | 0.013 | 0.013 | 0.033 |
| Average, all runs |  | 18.05 | 0.062 |  | 0.0094 | 0.0081 | 0.025 |

## TABLE 105. PARTICULATES, SCRUBBER DISCHARGE WATER

| Run Number | Concentration in[a] Water, mg/L | Captured per[b] hour, Kg | Average Load During Test MW-hr, Kg | Captured per MW-hr, Kg | Captured per Mg Feed, Kg | Captured per Mg Alloy, Kg |
|---|---|---|---|---|---|---|
| 1 | 67.8 | 7.84 | 7.40 | 1.06 | 0.76 | 2.78 |
| 2 | 134.7 | 15.6 | 6.87 | 2.27 | 1.63 | 5.95 |
| 3 | 74.3 | 8.59 | 7.18 | 1.20 | 0.86 | 3.14 |
| 4 | 89.3 | 10.3 | 6.42 | 1.61 | 1.62 | 4.22 |
| 5 | 92.7 | 10.7 | 6.0 | 1.79 | 1.80 | 4.69 |
| Average, all runs | 91.8 | 10.6 |  | 1.59 | 1.33 | 4.16 |

[a] Corrected for particulate concentration of 6.5 mg/L in inlet water.

[b] Scrubber discharge flow rate 1.93 $m^3$/min (509 gpm).

## TABLE 106. PARTICULATES, GRAVITY STACKS

| Run Number | mg Captured | Concentration in Gas, mg/dsm$^3$ | Emitted per hour Kg | Average Load During Test MW-hr/hr | Emitted per MW-hr Kg | Emitted per Mg feed Kg | Emitted per Mg Alloy Kg |
|---|---|---|---|---|---|---|---|
| 1 | 13.1 | 12.39 | 0.803 | 7.40 | 0.109 | 0.078 | 0.285 |
| 2 | 27.0 | 28.73 | 1.810 | 6.87 | 0.263 | 0.189 | 0.691 |
| 3 | 8.0 | 8.92 | 0.551 | 7.15 | 0.077 | 0.055 | 0.202 |
| 4 | 272.6 | 166.29 | 9.179 | 6.43 | 1.43 | 1.43 | 3.75 |
| 5 | 313.9 | 229.63 | 11.99 | 6.0 | 2.00 | 2.01 | 5.24 |
| Average, all runs | | 89.19 | 4.87 | | 0.776 | 0.752 | 2.03 |

Particulate concentration in the gas averaged about 89 mg/dsm$^3$, with an approximate range of 9 to 230 mg/dsm$^3$. Total particulate emitted from the gravity stacks was 4.87 Kg/operating hour, with an approximate range of 0.5 to 12 Kg/operating hour. In terms of operating parameters, the average amount of particulate emitted from the gravity stacks was about 0.8 Kg/MW-hr, 0.8 Kg/Mg raw material fed, and 2 Kg/Mg alloy produced. The variability in stack emissions will be discussed below.

Given in Table 107 is a summary of all particulate test results obtained. In this table we have combined results given in the preceding three tables, as appropriate, to give a complete picture of particulate generated by and emitted from the furnace. These results do not include tapping fumes. The total amount of particulate generated by the furnace, i.e., the sum of the particulate in the scrubber discharge water, scrubber gas, and gravity stack gas, averaged 15.54 Kg/operating hour. Of this amount, 4.93 Kg/hr or about 32 percent, was emitted to the atmosphere (sum of scrubber discharge gas and gravity stack gas). Almost all, 98.8 percent, of the emission was from the gravity stacks. The scrubber captured about 99.4 percent of the particulate withdrawn from beneath the furnace cover.

In terms of operating parameters, about 2.4 Kg of particulate were generated per MW-hr of furnace power. About 0.78 Kg of particulate was emitted per MW-hr of furnace power. This significantly exceeds the NSPS (does not apply to the furnace) of 0.23 Kg/MW-hr for furnaces producing H.C. FeMn. Again, most of the emission comes from the gravity stacks. Total particulate generated was about 2.1 Kg/Mg raw material fed and 6.2 Kg/Mg alloy produced. Total particulate emitted averaged 0.76 Kg/Mg raw material and 2.06 Kg/Mg alloy produced.

It is obvious that emissions from the gravity stacks dominate the overall emissions from the furnace. It is also obvious that emissions from the gravity stacks varied substantially for the two testing days. On the first day of testing (3/11/81) - Runs No. 1, 2, and 3), the furnace was running exceptionally smooth. Opacity meter readings were generally less than 4 percent. Very few episodes of furnace blows, gas jet blowing through mix seal on furnace cover, were observed. Most of these occurred during Run No.2 when the highest emissions for the day were obtained. Furnace operation

## TABLE 107. PARTICULATES, SUMMARY FURNACE 17

| Run Number | Total Generated per hour Kg | Emitted per hour Kg | Scrubber Efficiency % | Generated per MW-hr Kg | Emitted per MW-hr Kg | Generated per Mg Feed, Kg | Emitted per Mg Feed, Kg | Generated per Mg Alloy, Kg | Emitted per Mg Alloy, Kg |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 8.70 | 0.861 | 99.3 | 1.18 | 0.117 | 0.844 | 0.0836 | 3.086 | 0.306 |
| 2 | 17.42 | 1.854 | 99.7 | 2.54 | 0.269 | 1.824 | 0.1936 | 6.658 | 0.708 |
| 3 | 9.20 | 0.614 | 99.3 | 1.29 | 0.086 | 0.921 | 0.0613 | 3.365 | 0.225 |
| 4 | 19.57 | 9.249 | 99.3 | 3.05 | 1.441 | 3.061 | 1.44 | 7.999 | 3.779 |
| 5 | 22.79 | 12.066 | 99.3 | 3.80 | 2.013 | 3.823 | 2.023 | 9.963 | 5.273 |
| Average, all runs | 15.54 | 4.93 | 99.4 | 2.37 | 0.785 | 2.09 | 0.76 | 6.21 | 2.06 |

was quite different, however, on the second test day (3/12/81)-Runs No.4 and 5). The furnace was blowing when the test crew arrived on- site (about 8 a.m.) and was shutdown briefly to "slip" one electrode (change electrode holder position so that the electrode can be lowered further into the furnace). This seemed to decrease the furnace blows. However, at about 9:30 a.m. the furnace had to be shutdown again to repair a water leak. The furnace was restarted shortly after 12 noon. The furnace was not operating as smoothly as the previous day. Short blows were common and fumes rising from the cover were moderate-to-heavy. Opacity meters on the stacks were reading between 4 and 20 percent throughout Run No.4. Shortly after Run No.5 was started, furnace blows became quite frequent and severe; opacity monitors ranged from 20-80 percent for almost one hour. Plant personnel stated that the probable reasons for this occurrence was water under the cover from the leak that had been repaired earlier and possible damage to one electrode. About halfway through Run No.5 the furnace power input was lowered from the 6.5 to 7 MW range to 5.5 to 6 MW by reducing the applied voltage and the suspect electrode slipped. Furnace blows became infrequent and of minor intensity. Stack opacities decreased to 4 percent or less and remained at this level for the remainder of the test.

With respect to the overall test, the following comments are believed to accurately represent the situation, based on discussions with furnace operators and engineers and the experience of the RTI process observer. The raw material fed to the furnace contained very little fine material and would thus be expected to yield little entrained fine particulate. The furnace was operated at 10-20 percent below design power input, which is not unusual. This can potentially result in very stable furnace operation. Testing on 3/11/81 occurred when the furnace was operating very smoothly (but not abnormally so). Testing on 3/12/81 occurred when the furnace was operating very roughly (but not abnormally so). We would conclude, therefore, that testing occurred over a fairly wide range of conditions that would fall within the range of operations described as normal. We are, nonetheless, disturbed by the significant impact inclusion of the test data for gravity stack Runs No.4 and 5 have on the overall average. Averaging the results of all five runs is equivalent to saying that conditions oc curring during Runs

No.4 and 5 typically occur 40 percent of the furnace operating time. We do not believe this is the case. We conclude, therefore, that the five run average falls within the normal and typical range of emissions from the furnace but is probably in the high end of this range.

### 10.4.3 Organics

Given in Table 108 are the results for organics in the scrubber discharge water. The discussion is for Runs 2-5 only since the scrubber water sample extract for Run No.1 was lost in analysis. Organic concentration in the water averaged about 6 mg/L, with a range of 0.6 to 16.6 mg/L. About 90 percent of the organic was adsorbed on the suspended particulate matter. Total organic captured by the scrubber averaged about 0.7 Kg/hour or about 6.5 percent as much as the particulate matter captured. In terms of operating parameters, the scrubber captured 0.11 Kg/MW-hr, 0.1 Kg/Mg raw material fed, or 0.29 Kg/Mg alloy tapped.

Given in Table 109 are the results for organics in the outlet gas from the scrubber. Organic concentration in the gas averaged 111 mg/dsm$^3$ for all five runs, 104 mg/dsm$^3$ for runs 2-5. Total organic emitted through the scrubber stack averaged 0.38 Kg/operating hour (0.36 Kg/hour for runs 2-5). This is significantly greater than the particulate emissions of 0.062 Kg/hour. The data indicate that less than 5 percent of the organic in the scrubber outlet gas was adsorbed on the particulate matter, however, this number may be lower than the actual stack conditions since the sampling train filter is maintained at 121°C, well above the stack gas temperature of 16°C. Comparing data for Runs 2-5 on the scrubber discharge water and the outlet gas, the scrubber captured about 66 percent of the organic in the incoming gas.

In terms of operating parameters, emissions from the scrubber stack were 0.056 Kg/MW-hr, 0.046 Kg/Mg raw material fed, and 0.15 Kg/Mg alloy tapped.

Also given in Table 109 are the results for organic emissions from the gravity stacks. The five run average for organic concentration in this gas was 79 mg/dsm$^3$ (76 mg/dsm$^3$ for runs 2-5). Total organic emitted from the gravity stacks was 0.67 Kg/operating hour (0.65 Kg/hour for runs 2-5). Organic emissions were, therefore, less than 14 percent of the particulate

TABLE 108. ORGANICS, SCRUBBER DISCHARGE WATER

| Run Number | Concentration mg/L | Captured per hour, Kg | Captured per MW-hr, Kg | Captured per Mg Feed, Kg | Captured per Mg Alloy, Kg |
|---|---|---|---|---|---|
| 1 | Sample lost in analysis | | | | |
| 2 | 3.34 | 0.387 | 0.056 | 0.040 | 0.15 |
| 3 | 3.24 | 0.375 | 0.052 | 0.037 | 0.14 |
| 4 | 0.57 | 0.066 | 0.010 | 0.010 | 0.027 |
| 5 | 16.64 | 1.927 | 0.32 | 0.32 | 0.84 |
| Average runs, 2, 3, 4,& 5 | 5.94 | 0.689 | 0.11 | 0.10 | 0.29 |

## TABLE 109. ORGANIC, SCRUBBER OUTLET GAS AND GRAVITY STACK GAS

| Scrubber Gas | Run Number | mg Captured | Concentration in Gas, $mg/dsm^3$ | Emitted per hour, Kg | Emitted per MW-hr, Kg | Emitted per Mg Feed, Kg | Emitted per Mg Alloy, Kg |
|---|---|---|---|---|---|---|---|
| | 1 | 144 | 141 | 0.50 | 0.067 | 0.048 | 0.18 |
| | 2 | 135 | 139 | 0.47 | 0.068 | 0.049 | 0.18 |
| | 3 | 90 | 96 | 0.33 | 0.046 | 0.033 | 0.12 |
| | 4 | 71 | 70 | 0.24 | 0.037 | 0.037 | 0.098 |
| | 5 | 110 | 110 | 0.38 | 0.064 | 0.064 | 0.17 |
| Average, all runs | | | 111 | 0.38 | 0.056 | 0.046 | 0.15 |
| Gravity Stack Gas | 1 | 96 | 91 | 0.76 | 0.10 | 0.074 | 0.27 |
| | 2 | 43 | 46 | 0.34 | 0.049 | 0.035 | 0.13 |
| | 3 | 118 | 132 | 0.93 | 0.13 | 0.093 | 0.34 |
| | 4 | 86 | 52 | 0.61 | 0.096 | 0.096 | 0.25 |
| | 5 | 102 | 74.6 | 0.72 | 0.120 | 0.12 | 0.32 |
| Average, all runs | | | 79.0 | 0.67 | 0.10 | 0.084 | 0.26 |

emissions from the gravity stacks. Less than 5 percent of the organic was adsorbed on the particulate matter. Here again, this number could be low since the stack temperature was less than 30°C and the sample train filter was maintained at 120°C.

Given in Table 110 is a summary of data in the preceding two tables. Partial data are given for Run No.1 since the organic extract of the scrubber water for this run was lost in analysis. All averages are, therefore, for Runs 2-5. The total amount of organic generated per operating hour averaged 1.69 Kg. The emission rate was 1.0 Kg/hour. Thus, 59 percent of the organic matter generated was emitted to the atmosphere. Based on runs 2-5, the furnace generates about 10 percent as much organic matter as it does particulate and emits about 17 percent as much organic matter as it does particulate.

In terms of operating parameters, the furnace generated 0.26 Kg organic per MW-hr, 0.23 Kg/Mg raw material fed, and 0.69 Kg/Mg alloy tapped. Emission rates were 0.15, 0.13, and 0.40 Kg, respectively, for the parameters above.

### 10.4.4 Benzo(a)Pyrene

Given in Table 111 are the results obtained for BaP in the scrubber discharge water. Samples from Run No.1 were lost in analysis. The average BaP concentration in the scrubber discharge water was 1.3 μg/L. All of the BaP was adsorbed on the suspended particulate matter. The scrubber captured an average of 0.15 grams of BaP per hour (range 0.08 to 0.24). This is about $2.2 \times 10^{-2}$ percent of the organic captured by the scrubber. In terms of operating parameters the scrubber captured $2.2 \times 10^{-2}$ grams per MW-hr, $1.8 \times 10^{-2}$ grams per Mg raw material fed, and $5.8 \times 10^{-2}$ grams per Mg alloy tapped.

Given in Table 112 are the results obtained for BaP in the outlet gas from the scrubber. BaP was detected in only two of the five runs. All of the BaP was adsorbed on the particulate matter. The average BaP concentration in the gas was 0.30 μg/dsm$^3$ (0.16 μg/dsm$^3$ for runs 2-5). Because of the relatively low gas flow from this source, the emission rate is only $1.1 \times 10^{-3}$ grams per hour ($5 \times 10^{-4}$ grams/hour average for Runs 2- 5).

TABLE 110. SUMMARY, ORGANICS -- COVERED FeMn FURNACE

| Run Number | Generated per hour Kg | Emitted per hour Kg | Generated per MW-hr Kg | Emitted per MW-hr Kg | Generated per Mg Feed Kg | Emitted per Mg Feed Kg | Generated per Mg Alloy Kg | Emitted per Mg Alloy Kg |
|---|---|---|---|---|---|---|---|---|
| 1 | >1.26 | 1.26 | >0.167 | 0.167 | >0.122 | 0.122 | >0.45 | 0.45 |
| 2 | 1.197 | 0.81 | 0.173 | 0.117 | 0.124 | 0.084 | 0.46 | 0.31 |
| 3 | 1.635 | 1.26 | 0.228 | 0.176 | 0.163 | 0.126 | 0.60 | 0.46 |
| 4 | 0.916 | 0.85 | 0.143 | 0.133 | 0.143 | 0.133 | 0.375 | 0.348 |
| 5 | 3.027 | 1.10 | 0.504 | 0.184 | 0.504 | 0.184 | 1.33 | 0.49 |
| Average runs 2, 3, 4 & 5 | 1.69 | 1.00 | 0.262 | 0.152 | 0.2340 | 0.132 | 0.691 | 0.40 |

## TABLE 111. BaP, SCRUBBER DISCHARGE WATER

| Run Number | Concentration[a] μg/L | Captured per hour, gms | Captured per MW-hr, gms | Captured per Mg Feed, gms | Captured per Mg Alloy, gms |
|---|---|---|---|---|---|
| 1 | ?[b] | | | | |
| 2 | 2.1 | 0.24 | 0.035 | 0.025 | 0.092 |
| 3 | 1.43 | 0.17 | 0.024 | 0.017 | 0.062 |
| 4 | 0.66 | 0.076 | 0.012 | 0.012 | 0.031 |
| 5 | 0.95 | 0.11 | 0.018 | 0.018 | 0.048 |
| Average runs 2, 3, 4, & 5 | 1.29 | 0.15 | 0.022 | 0.018 | 0.058 |

[a] 100% of BaP was associated with the suspended solids.

[b] Extract of suspended solids lost in analysis. No BaP detected in aqueous phase.

## TABLE 112. SCRUBBER OUTLET GAS AND GRAVITY STACK DISCHARGE GAS

| Location | Run Number | μg Captured | Concentration in Gas, μg/dsm$^3$ | Emitted per hour, gms | Emitted per MW-hr, gms | Emitted per Mg Feed, gms | Emitted per Mg Alloy, gms |
|---|---|---|---|---|---|---|---|
| Scrubber Outlet Gas | 1 | 0.9 | 0.88 | 0.0031 | 0.0004 | 0.0003 | 0.001 |
| | 2 | ND | - | - | - | - | - |
| | 3 | 0.6 | 0.64 | 0.0022 | 0.0003 | 0.0002 | 0.0008 |
| | 4 | ND | - | - | - | - | - |
| | 5 | ND | - | - | - | - | - |
| Average | | | 0.30 | 0.0011 | 0.0001 | 0.0001 | 0.0004 |
| Gravity Stack Discharge | 1 | 0.7 | 0.66 | 0.0056 | 0.00075 | 0.0005 | 0.002 |
| | 2 | ND | - | - | - | - | - |
| | 3 | ND | - | - | - | - | - |
| | 4 | ND | - | - | - | - | - |
| | 5 | ND | - | - | - | - | - |
| Average | | | 0.13 | 0.0011 | 0.0001 | 0.0001 | 0.0004 |

In terms of operating parameters, emissions from this source averaged (all five runs) 1 x $10^{-4}$ g/MW-hr, 1 x $10^{-4}$ g/Mg raw material fed, and 4 x $10^{-4}$ g/Mg alloy tapped.

Also given in Table 112 are the BaP results obtained for gases emitted through the gravity stack. BaP was detected only in Run No.1. The particulate matter contained 100 percent of the BaP detected. The concentration of BaP measured in that run was 0.66 μg/$dsm^3$, yielding a five run average of 0.13 μg/$dsm^3$. The total amount emitted was 1.1 x $10^{-3}$ grams per hour (five run average), the same as measured for the scrubber outlet gas.

Given in Table 113 is a summary of the BaP data presented in the previous two tables. The total amount of BaP generated by the furnace (average of Runs 2-5) was 0.15 grams per hour. Of this 6 x $10^{-4}$ grams per hour (0.4 percent) was emitted to the atmosphere. Thus, about 9 x $10^{-3}$ percent of the organic matter generated is BaP and about 6 x $10^{-5}$ percent of the organic matter emitted is BaP.

## 10.5 WASTEWATER TREATMENT

As described previously, furnace scrubber water discharge is combined with oxygenated water from the electrolytic units operations. This wastewater flows directly to the final ponds (about 100 acres) where solids settle out before the water is discharged to the river. Samples of the pond influent and pond effluent were taken with an automatic compositing sampler over a 24-hour period (1 p.m. 3/11/81 to 1:30 p.m. 3/12/81). The pond outlet flow rate over this time period was 10.2 $m^3$/min (2700 gpm). The samples were homogenized and split in the RTI laboratory. One portion of the sample was filtered for suspended solid determination and the filtrate and solids further analyzed by RTI for organics and BaP. A second portion of the sample was analyzed for EPA designated priority pollutants by Stewart Laboratories, Inc. A third portion was used for tests discussed in the following section on solid wastes.

Given in Table 114 are the suspended solids, organics, and BaP data for the Marietta wastewater treatment pond system. The influent suspended solids concentration was slightly more than 3000 mg/L. Total solids

## TABLE 113. SUMMARY, BaP -- COVERED FeMn Furnace

| Run Number | Generated per hour gms | Emitted per hour gms | Generated per MW-hr gms | Emitted per MW-hr gms | Generated per Mg Feed gms | Emitted per Mg Feed gms | Generated per Mg Alloy gms | Emitted per Mg Alloy gms |
|---|---|---|---|---|---|---|---|---|
| 1 | >0.0087 | 0.0087 | >0.000475 | 0.000475 | >0.0008 | 0.0008 | >0.003 | 0.003 |
| 2 | 0.24 | - | 0.035 | - | 0.025 | - | 0.092 | - |
| 3 | 0.172 | 0.0022 | 0.0243 | 0.0003 | 0.0172 | 0.0002 | 0.0628 | 0.0008 |
| 4 | 0.076 | - | 0.012 | - | 0.012 | - | 0.031 | - |
| 5 | 0.11 | - | 0.018 | - | 0.018 | - | 0.048 | - |
| Average runs 2, 3, 4, & 5 | | | | | | | | |
| | 0.15 | 0.0006 | 0.022 | 0.0001 | 0.018 | 0.00005 | 0.058 | 0.0002 |

[a] Blanks indicate emission rate was below the detection limit.

## TABLE 114. TSS, ORGANIC, AND BaP IN MARIETTA PLANT WASTEWATER

| Component | Concentration in Sample | Entering Pond[a] per 24 hours, Kg |
|---|---|---|
| A. Wastewater Pond Inlet | | |
| Suspended Solids | 3,023 mg/L | 44,400 |
| Organics | | |
| Dissolved in Water | 0.5 mg/L | 7.3 |
| Adsorbed on Solids | 2.4 mg/L | 35 |
| Total | 2.9 mg/L | 42 |
| BaP | | |
| Dissolved in Water | ND[b] μg/L | 0 |
| Adsorbed on Solids | 2.4 μg/L | 0.035 |
| Total | 2.4 μg/L | 0.035 |
| | | Discharged from Pond[a] per 24 hours, Kg |
| B. Wastewater Pond Outlet | | |
| Suspended Solids | ND mg/L | 0 |
| Organics, Total | ND mg/L | 0 |
| BaP, Total | ND μg/L | 0 |

[a] Based on pond outlet flow rate of 10.2 $m^3$/min (2700 gpm).

[b] Below detection limits of: TSS, 0.05 mg/L; organics, 0.05 mg/L; BaP, 0.25 μg/L.

discharged into the pond per day were calculated to be about 44,400 Kg based on the outlet flow rate from the pond system of 10.2 $m^3$/min. Total organic concentration in the pond influent water was 2.9 mg/L (42 Kg/day). Of this, 0.5 mg/L was dissolved in the water and 2.5 mg/L adsorbed on the suspended solids. The organic content of the solids was, therefore, 0.08 percent.

A total of 2.4 μg/L of BaP (0.035 Kg/day) was found in the portion of the sample analyzed at RTI, which differs somewhat from the value determined by Stewart Laboratories, Inc. on a separate portion of the sample. All of the BaP was adsorbed on the suspended solids. BaP, therefore, constituted 0.08 percent of the organic matter, 0.1 percent of the organic matter ad sorbed on the solids, and $8 \times 10^{-5}$ percent of the solids.

Water discharged from the ponds contained no detectable solids, organic, or BaP. Detection limits were, respectively, 0.05 mg/L, 0.05 mg/L, 0.25 μg/L. Thus, the ponding system, which allows solids settling and holding time, resulted in a substantial improvement in water quality. Removal of suspended solids results in an 83 percent reduction in organics and a 100 percent reduction in BaP.

These samples were also analyzed for priority pollutants. Given in Table 115 are the results of these analyses for only those components found in either sample. A complete listing of all compounds analyzed for can be found in Tables 90-94, Section 9.

It can seen that there were only a few organic priority pollutants in the pond inlet water and these were all at low concentrations. This can be attributed to a combination of: (1) low organic concentrations in scrubber discharge waters, likely due to significant undercover combustion of furnace gas in the mix-sealed furnaces, and (2) to oxidation by residual oxygen from treatment of electrolytic plant wastewater. All metals on the priority pollutant tests were detected in the pond inlet water with concentrations varying from 6 μg/L of mercury to 52 mg/L for chromium. The final pond discharge contained either none or substantially less of all components found in the inlet water except chlorobenzene and silver. We have no explanation for the chlorobenzene result since the water is not chlorinated. No carcinogenic organic compounds were detected in the effluent.

## TABLE 115. PRIORITY POLLUTANTS DETECTED IN PLANT WASTEWATERS

| Component | Pond Inlet Concentration μg/L | Pond Outlet (Plant Final Discharge) Concentration, μg/L) |
|---|---|---|
| Chlorobenzene | ND | <10 |
| Methylene chloride | <10 | <10 |
| Acenaphthylene | <10 | ND |
| Acenaphthene | <10 | ND |
| Anthracene | <10 | ND |
| Fluoranthene | 71 | 15 |
| Pyrene | 54 | <10 |
| Chrysene | 16 | ND |
| Benzo(a)anthracene | 10 | ND |
| Benzo(b)fluoranthene | <10 | ND |
| Benzo(a)pyrene | 13 | ND |
| Antimony | 164 | 13 |
| Arsenic | 1,930 | 3 |
| Beryllium | <10 | <10 |
| Cadmium | 310 | <1 |
| Chromium | 52,000 | 9 |
| Copper | 810 | 20 |
| Lead | 1,020 | <10 |
| Mercury | 6 | <1 |
| Nickel | 2,600 | 100 |
| Thallium | <100 | <100 |
| Selenium | 26 | 11 |
| Silver | 58 | 220 |

## 10.6 LEACHING TEST, SOLIDS IN WWT POND INLET SLURRY

The plant slurries dusts collected by the emission control equipment, adds this to oxygenated fluid wastes from the electrolytic operations, and discharges this to the wastewater ponds. Solids which settle out are dredged and landfilled. Rather than trying to obtain a sample of the dredging or of the material in the landfill, a composite sample of the pond influent was obtained and the solids filtered out. We believe this is a good representation of the material which will eventually be landfilled.

The solids filtered from the influent were analyzed by AAS for nine metals on EPA's Priority Pollutant list. Five of the elements (Be, Cd, Cr, Pb, and Tl) are present (see Table 116) in concentrations which may be of some concern. Arsenic and selenium may also be of concern, but this cannot be stated with confidence.

The solids were then subjected to leaching following procedures given in the Federal Register 40 CFR Part 261, Appendix II, May 19,1980. The leachate analysis is given in column 3 of the table. None of the elements equal or exceed the permissible concentration given in 40 CFR Part 261.24. Thus, on this basis the solid is nonhazardous.

Given in the last columns of the table are the actual amount extracted and the percentage of the element extracted. Less than 1 percent of each of four elements was extracted. Elements with higher extraction rates are antimony (8.6 percent), cadmium (5.6 percent), thallium (8.6 percent) and possibly selenium.

## TABLE 116. LEACHING TESTS, MARIETTA PLANT WWT POND INLET SOLIDS

| Element | Concentration in Original Sample, μg/g Solid | Concentration in Leachate, mg/L | Amount Leached, μg/g Solids | % of Element |
|---|---|---|---|---|
| Antimony | 3.0 | $1.29 \times 10^{-2}$ | 0.258 | 8.6 |
| Arsenic[a] | 572 | 0.112 | 2.24 | 0.4 |
| Beryllium | 5.07 | $2.1 \times 10^{-4}$ | $4.19 \times 10^{-3}$ | $8 \times 10^{-2}$ |
| Cadmium | 73.5 | 0.204 | 4.08 | 5.6 |
| Chromium | 20,700 | 0.193 | 3.86 | $2 \times 10^{-2}$ |
| Lead | 436 | $<1 \times 10^{-3}$ | $<2 \times 10^{-2}$ | $5 \times 10^{-3}$ |
| Mercury | <0.62 | $<1.2 \times 10^{-2}$ | <0.25 | ? |
| Selenium | <2.3 | $<6 \times 10^{-2}$ | <1.25 | 54 ? |
| Thallium | 13.3 | $5.7 \times 10^{-3}$ | 1.15 | 8.6 |

[a] Possible analytical interference.

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# APPENDICES

Contact the Project Officer, R. C. McCrillis, for detailed test data.

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